UNIVERSITY OF CALIFORNIA PUBLICATIONS
IN
AGRICULTURAL SCIENCES

Vol. 1, No. 5, pp. 63-126 October 23, 1913

STUDIES UPON INFLUENCES AFFECTING THE PROTEIN CONTENT OF WHEAT

BY
G. W. SHAW

In 1905 the Merchants' Exchange of San Francisco, the State Board of Trade, the Sacramento Valley Development Association, and the more prominent millers and grain dealers of California called the attention of the Agricultural Department of the University to the fact that the milling trade found it necessary to import many hundred tons of wheat per year to maintain the quality of California flour owing to the low gluten content of the wheat grown in the state.

With the view of ascertaining the causes of such an undesirable condition, investigations were begun under an appropriation made by the Legislature at the session of 1906 (Senate Bill no. 10, entitled "An Act to provide for the improvement of cereal crops of California and appropriating money therefor"). The investigations are still under way, the bill having been re-enacted at the legislative session of 1908 and again in 1910.

The chief points for study in these investigations are: (1) To determine the effect of changes of environment upon the growth of cereals, particularly as regards the composition of the wheat kernel and with special reference to the causes of the production of a low protein content; (2) to discover or produce such wheat as will yield the largest profit per acre for the farmer, and will supply the millers with wheat of superior quality; (3) to conduct similar experiments with oats, barley, *and other cereals as may be desirable;* (4) to determine the effectiveness of various methods of culture as affecting the production of cereals.

The nature of this work is such that no permanent results can be secured from one or two seasons' operations. The element of time is an all-essential one for the solution of such problems. This would be true even though the problem was merely the development of wheats giving higher yields than those now being grown in the State, but *with the introduction of the problem of increasing the gluten content,* the element of time is even of greater importance. With this in view, the experiments were so planned that while the final results could not be expected for several years, it was possible to obtain data of importance bearing upon the entire question of cereal culture each year, material progress thus being assured.

As early as 1882 Clifford Richardson called attention to the fact that wheats from the Pacific Coast were relatively low in their protein content, and numerous analyses of California grown wheats made at the California Agricultural Experiment Station under the direction of Dr. E. W. Hilgard, in the earlier years, also showed the same condition to exist.

That this condition exists is undoubtedly true, whatever the causes may be. To bear witness to the fact the following summary is given of analyses of white wheats grown in several different states, as compared with the analyses of 149 samples of wheats of the same class grown in California in the same years. For the sake of comparison also the average results obtained from the analysis of 49 hard winter wheats grown in Kansas the same season are included, as well as those of three soft white wheats grown in Kansas from seed originally obtained from the state of Washington.

TABLE SHOWING THE PROTEIN CONTENT OF WHITE WHEATS GROWN IN DIFFERENT STATES IN THE SAME SEASON

State	Number of samples	Total protein *Dry basis*
California	149	9.77
Idaho	46	10.88
Nevada	34	16.18
Montana	6	14.24
Utah	10	15.20
Washington	177	12.98
Kansas (hard winter)	49	13.25
Kansas (white wheats)*	3	10.57

* Grown in Kansas from seed secured from the State of Washington.

In practically all of the former studies of this subject the plan has been to transfer the seed from one point to another and thus change the environmental conditions, and from the results so secured to attempt to draw general conclusions. Under such conditions, changes, not merely in environment, but also in soil, were accomplished, thus introducing too many variables. In the experiments here recorded two general methods have been followed: (*a*) the production of numerous varieties of wheat in the field on a small area of uniform soil and varying other condition of growth than the soil, and (*b*) growing wheat from the same seed under the same conditions on soils of widely different origin placed under the same cultural and climatic influences. The large and important question involved is the cause or causes of the relatively low gluten content of wheat grown under California conditions. In this connection, it is particularly desirable to know whether or not such tendency to change as exists is constant; whether it is due to some climatic influence, the time of cutting, the time of seeding, the bleaching action of the sun, the effect of early and late application of moisture, the effect of cold nights, of varying amounts of sunshine during the ripening period, or to some induced or inherent condition of the soil. The work which we have conducted has aimed at the solution of all of the questions just mentioned and consisted of several parts each of which dealt with one of the questions involved.

Variation in the Protein Content of Wheat

Seasonal Variation.—It has been observed that from season to season there is a marked variation in the protein content of wheat even though grown upon the same soil, a seeming indication that the seasonal factor is considerably greater than the soil factor in protein formation. This may be shown from a number of samples grown during the course of the experiments, some of which are given below. These wheats have been grown each year on the same soil and under the same cultural conditions at the University Farm at Davis, California.

TOTAL PROTEIN IN DRY MATTER

	1906	1907	1908	1909	1910	1911	1912
Kubanka	9.68	9.90	14.71	14.30	14.87	10.60	14.93
Crimean	10.38	11.38	11.75	13.27	12.18	10.60	12.11
Little Club Av. of 5 plats			10.29	9.78	9.98	....	13.00

That the quantity of available nitrogen in the soil has comparatively little bearing, if any, beyond its necessity in sufficient quantity to insure the normal growth of the plants, is indicated on a series of fertilizer plats of very uniform land, discussed further on in this paper. The seasonal effect is apparent, however, from the check plats in the same series.

Varietal Variation.—Variation in protein content occurs between different varieties of wheat, even though the strain be a pure one and the soil conditions under which they are grown be the same. The analyses given below are from plants of pure strain grown during the course of breeding experiments in centgener plats under just as nearly the same conditions as it is possible to secure in the field. The soil was uniform and the plants were 4 inches apart each way and seeded at a uniform depth of 2 inches.

GROWN AT DAVIS, 1908

	Number of samples	Per cent protein
Little Club	163	11.83
Propo	38	12.20
Fretes	111	13.46

GROWN AT CERES, 1908

	Number of samples	Per cent protein
Chul	53	14.98
Kharkov	50	13.95
White Australian	70	14.69

In addition to the varietal variations here shown, the above figures are of interest in showing that Kharkov, which is a hard winter wheat, when grown under California conditions in the same season does not carry a higher percent of protein than a good quality of the White Australian belonging to the white wheat class.

Variation in Individual Plants.—That there is a wide difference in the ability of individual plants to elaborate protein in the grain is shown from the analysis of a number of varieties grown under like conditions on the same character of soils. These plants were all grown in the same season in centgener plats, the plants being four (4) inches apart each way, and seeded at uniform depth by means of a centgener planter. The outside rows were all cut away at harvest and discarded, so that none of the plants shown here represent outside rows, but all had a uniform feeding area on uniform land.

In each of the lots shown in Table 1 it will be noted that there is a great variation between individual plants even when grown under exactly the same climatic and cultural conditions. The variation in individual plants of the variety White Australian ranged from a minimum of 9.06 to 15.31 per cent total protein, or a variation of 6.25 per cent within 25 plants, and the range in Little Club is even greater, being from 7.12 to 15.22.

Such evidence as that presented above would seem to throw the main factors determining the protein content of wheats, and inferentially other grains, externally, primarily upon some climatic influence, and secondarily upon the internal factors of variety and individuality of the plant itself. It seems certain that the individuality of the wheat plant is just as potent in determining the protein content of the grain as is the individuality of the dairy cow in determining the fat content of her milk and that it is just as impossible to feed protein into wheat by increasing the available nitrogen of the soil as it is to feed butter-fat into a cow's milk.

Following these general considerations of some of the external and internal factors bearing upon the question of protein variation, attention is turned to more restricted phases of the problem.

TABLE 1 SHOWING CERTAIN VARIATIONS BETWEEN INDIVIDUAL PLANTS OF WHEAT

Club-California No. 459					White Australian-California No. 452					Propo				
Cent gene No.	Number kernels in plant	Weight of kernels per plant (Grams)	Per cent nitrogen in kernels	Per cent total protein	Cent-gener No.	Number kernels in plant	Weight of kernels per plant (Grams)	Per cent nitrogen in kernels	Per cent total protein	Cent-gener No.	Number kernels in plant	Weight of kernels per plant (Grams)	Per cent nitrogen in kernels	Per cent total protein
4718	219	10.241	1.714	9.74	4813	103	3.7808	2.182	12.39	7317	144	7.0617	1.793	10.18
4704	244	10.538	2.614	14.85	4818	119	5.0306	1.835	10.42	7315	150	7.2607	1.864	10.09
4711	244	10.451	2.646	15.03	4821	121	5.0302	2.345	13.32	7316	150	5.9803	2.078	11.80
4722	246	11.143	1.279	7.26	4810	123	4.9826	1.740	9.88	7302	168	8.8266	1.944	11.04
4723	254	11.254	2.031	11.54	4809	128	5.1400	1.954	11.10	7310	173	8.1147	1.786	10.14
4701	263	12.480	2.232	12.68	4816	128	5.8740	1.732	9.84	7318	173	9.2274	1.852	10.52
4721	264	9.397	2.758	15.67	4814	135	5.5290	1.752	9.95	7320	199	9.5840	1.776	10.09
4707	266	11.797	2.359	13.40	4819	139	5.9616	1.609	9.14	7311	200	7.7578	1.855	10.54
4724	270	12.176	2.473	14.05	4820	144	6.1408	3.459	13.97	7303	210	10.7348	1.419	8.06
4702	272	12.480	2.232	12.74	4817	150	5.2002	2.002	11.47	7308	218	10.5668	1.547	8.79
4720	278	11.401	1.866	10.60	4823	151	6.6950	1.321	7.50	7314	219	11.4692	1.725	9.80
4716	281	13.061	1.889	10.73	4803	152	6.4767	1.794	10.19	7309	229	12.5288	1.779	10.10
4709	290	12.004	1.824	10.36	4806	155	6.9606	1.595	9.06	7312	245	10.7326	1.954	11.10
4713	294	12.054	1.907	10.59	4822	157	6.6148	2.696	15.31	7321	261	12.9620	2.415	13.72
4719	295	11.897	1.476	8.38	4811	159	6.3916	2.417	13.73	7313	284	12.1798	2.499	14.19
4705	296	12.274	2.614	9.03	4824	166	5.9324	2.109	11.98	7307	306	13.173	2.362	13.45
4712	299	13.104	2.485	14.12	4812	176	8.2980	1.722	9.78	7319	325	13.9718	2.312	13.13
4717	303	12.536	1.597	9.07	4807	182	8.6880	2.069	11.75	7306	338	13.0815	1.629	9.20
4715	304	13.003	1.995	11.33	4805	187	8.5149	1.830	10.39	7304	300	8.9246	1.946	11.05
4710	325	13.825	1.931	10.97	4815	196	8.1176	1.928	10.95	7305	310	7.7959	1.821	10.34
4708	347	13.850	2.141	12.16	4825	203	7.1600	1.979	11.24	....	......	....	....	....
4714	376	17.074	2.010	11.42	4803	286	6.7326	2.133	12.12	....	......	....	....	....
4706	412	17.119	2.856	16.22	4804	206	9.5090	1.770	10.05	....	......	....	....	....
4703	539	24.388	1.254	7.12	4802	232	7.5580	1.713	9.73	....	......	....	....	....
4725	555	24.672	1.432	8.13	4801	257	1.9316	1.704	9.69	....	......	....	....	....
Av.	309	13.433	2.064	11.49		163	6.7224	1.936	11.00		244	10.0967	1.9178	10.89

THE CONSTANCY OF CHANGE TOWARD STARCHINESS IN WHEAT KERNELS

The phase presented in this portion of the study has to do with the tendency of varieties toward a constancy of change from the type seeded. The central idea was that if there really existed a strong tendency toward the development of a distinctly starchy nature, under the conditions which here obtain, not only would the progeny of perfectly typical glutenous kernels show a considerable number of more or less starchy kernels and a lower protein (gluten) content, but spotted kernels would show a similar change in their progeny; and the entirely changed kernels, carrying 100 per cent of starchy kernels in the original, would show a still lower percent of typical kernels and a very low protein content in the progeny, remaining, in fact, essentially starchy.

The plan of the experiment which extended over the seasons of 1906–08, inclusive, was to grow a number of varieties of wheat at several points in the state, the physical and chemical condition of the originals used being first determined, and to follow the changes in the progeny in each instance during the season and the total period of the trials.

The experiments were conducted in the fields at Modesto, Ceres, and Tulare as typical of San Joaquin Valley conditions, and at Yuba City and Davis as representative of Sacramento Valley conditions. In order to follow better such changes as occurred, by the eye as well as by analysis, such varieties of wheat were selected as had typical kernels of distinctive appearance.

THE NITROGEN OF TYPICAL vs. SPOTTED WHEAT KERNELS OF THE SAME VARIETY

At the outset a number of varieties of wheat were hand-separated into three primary lots or groups, based upon the physical appearance of the kernels, as follows:

Group I, consisting entirely of perfectly typical (glutenous) kernels;

Group II, consisting of kernels of the same varieties of wheat

which were of an entirely starchy character, showing no typical kernels whatsoever;

Group III, consisting of kernels of the same varieties of an intermediate appearance upon which the percentage of typical kernels was determined in each case.

Each of these lots was subjected to a determination of the nitrogen content in order to ascertain whether this distinctive appearance of the kernels was a fair indication of their nitrogen content.

The results are subtended:

NITROGEN CONTENT (DRY BASIS)

	Typical kernels	More or less starchy kernels
Sample no. 1	1.75	1.45
Sample no. 2	1.75	1.54
Sample no. 3	1.67	1.54
Sample no. 4	1.85	1.57
Sample no. 5	1.98	1.74
Sample no. 6	2.13	1.78
Sample no. 7	2.09	1.73
Sample no. 8	2.03	1.74
Sample no. 9	1.98	1.52
Sample no. 10	2.02	1.90
Sample no. 11	2.12	1.90
Sample no. 12	2.27	2.08
Sample no. 13	1.82	1.68
Sample no. 14	2.03	1.68
Sample no. 15	2.33	1.83
Sample no. 16	1.83	1.62
Average	1.97	1.69

These results seem to show that the physical appearance of the grain may, in general at least, be taken as a fair index of its relative gluten or protein content.

Each of the above described groups was drill-seeded in a number of rows in a uniform manner and under uniform soil conditions and given the same cultural treatment.

The results of the experiments in 1906 are tabulated below:

TABLE 2.—SHOWING PHYSICAL AND CHEMICAL DEVIATION OF WHEAT KERNELS FROM TYPE SEEDED IN 1906

MODESTO

Lab. No.	Name	Condition of seed	Date of harvest	Per cent of typical kernels	Number kernels in 10 grains	As analyzed: Moisture	As analyzed: Total nitrogen	As analyzed: Protein	As analyzed: Ash	Calculated to dry basis: Total nitrogen	Calculated to dry basis: Protein	Calculated to dry basis: Ash
644	Kubanka	Clear	Original	100.0	203	9.99	2.10	11.93	1.83	2.33	13.25	2.03
709	Kubanka	....	June 27	98.9	252	10.98	2.33	13.24	1.99	2.62	14.91	2.24
647	Kubanka	Spotted	Original	0.0	206	10.21	1.81	10.27	1.88	2.01	11.46	2.09
711	Kubanka	....	June 27	89.4	216	10.87	2.31	13.16	1.98	2.59	14.75	2.22
650	Kubanka	White	Original	0.0	235	9.45	1.66	9.41	1.84	1.83	10.43	2.03
713	Kubanka	....	June 27	96.9	195	10.95	2.23	13.68	1.89	2.50	14.20	2.12
653	Chul	Dark	Original	100.0	......	10.27	2.05	11.68	1.84	2.39	14.62	2.05
715	Chul	....	June 12	94.1	219	11.96	1.81	10.36	2.00	2.05	11.69	2.25
655	Chul	Spotted	Original	0.0	215	10.67	2.00	11.40	1.90	2.24	12.77	2.20
717	Chul	....	June 12	91.6	218	11.13	1.96	11.16	2.00	2.21	12.56	2.25
338A	Turkey Red	Clear	Original	100.0	320	12.74	1.59	9.05	1.74	1.82	10.37	1.99
338A3	Turkey Red	....	June 27	98.0	314	11.28	2.08	11.80	2.08	2.34	14.34	2.34
338B	Turkey Red	Spotted	Original	0.0	310	12.34	1.42	8.09	1.72	1.62	9.23	1.96
338B3	Turkey Red	....	June 27	92.2	309	11.19	1.98	11.24	2.02	2.23	12.71	2.27
200	Kubanka	Spotted	Original	38.3	250	13.56	2.13	12.14	1.88	2.47	14.04	2.18
725	Kubanka	....	June 21	97.9	246	11.01	1.96	11.16	1.88	2.20	12.51	2.11
505	Marouani	Spotted	Original	43.2	216	11.36	1.70	9.68	1.74	1.94	11.06	1.96
725	Marouani	....	July 14	95.3	171	11.50	2.15	12.20	1.98	2.43	13.71	2.24
573	Turkey Red	Clear	Original	100.0	315	14.65	2.04	11.64	1.94	2.39	13.39	2.27
733	Turkey Red	....	June 27	99.3	306	10.33	2.16	12.28	2.02	2.40	13.63	2.25

TABLE 2.—SHOWING PHYSICAL AND CHEMICAL DEVIATION OF WHEAT KERNELS FROM TYPE SEEDED IN 1906—(*Concluded*)

YUBA CITY

Lab. No.	Name	Condition of seed	Date of harvest	Per cent of typical kernels	Number kernels in 10 grains	As analyzed: Moisture	As analyzed: Total nitrogen	As analyzed: Protein	As analyzed: Ash	Calculated to dry basis: Total nitrogen	Calculated to dry basis: Protein	Calculated to dry basis: Ash
644	Kubanka	Clear	Original	100.0	203	9.99	2.10	11.93	1.83	2.33	13.25	2.03
645	Kubanka	....	July 2	55.6	217	10.11	1.92	10.91	2.04	2.14	12.12	2.26
647	Kubanka	Spotted	Original	0.0	206	10.21	1.81	10.27	1.88	2.03	11.56	2.09
648	Kubanka	....	July 2	20.3	197	10.38	1.82	10.34	1.98	2.03	11.56	2.21
650	Kubanka	White	Original	0.0	235	9.45	1.66	9.41	1.84	1.83	10.42	2.03
651	Kubanka	....	July 2	63.5	205	12.79	1.70	9.72	2.16	1.95	11.15	2.48
653	Chul	Dark	Original	100.0	210	10.27	2.05	11.68	1.84	2.39	14.62	2.05
645	Chul	....	June 30	59.4	203	10.50	1.81	10.28	1.99	2.03	11.56	2.22
656	Chul	Spotted	Original	0.0	215	10.67	1.73	9.80	1.90	1.93	11.00	2.11
657	Chul	....	June 30	76.0	221	10.31	1.94	11.02	2.00	2.17	12.36	2.12
659	Chul	Light	Original	0.0	216	10.42	1.44	8.17	1.77	1.61	9.13	2.99
660	Chul	....	June 30	52.0	220	12.49	1.87	10.64	2.00	2.12	12.04	2.28
338A	Turkey Red	Clear	Original	100.0	330	12.74	1.59	9.05	1.74	1.71	9.71	1.99
338A1	Turkey Red	....	July 7	65.3	298	10.41	1.77	10.05	1.87	1.98	11.25	2.09
338B	Turkey Red	Spotted	Original	0.0	310	12.34	1.42	8.09	1.72	1.62	9.20	1.96
338B1	Turkey Red	....	July 7	67.3	302	10.15	1.77	10.03	1.97	1.97	11.20	2.19
677	Kubanka	Spotted	Original	23.7	232	10.78	1.50	8.59	1.84	1.68	9.56	2.06
678	Kubanka	....	July 2	63.4	230	10.31	1.91	10.84	2.05	2.13	12.04	2.29
671	Kahla	Spotted	Original	75.2	208	10.34	2.15	12.20	2.17	2.40	13.55	2.42
672	Kahla	....	July 5	53.0	207	10.04	2.06	11.76	2.19	2.30	13.11	2.43
666	Kharkov	Spotted	Original	93.1	301	10.47	2.13	12.10	2.15	2.38	13.68	2.40
861	Kharkov	....	July 5	83.9	310	11.64	1.89	11.75	2.07	2.18	12.44	2.40
862	Beloglina	Spotted	Original	59.9	310	10.49	1.81	10.28	2.00	2.02	11.48	3.56
863	Beloglina	....	June 23	77.7	314	12.72	1.83	10.40	2.22	2.09	11.91	2.54

DISCUSSION OF 1906 RESULTS

Examination of the 1905–06 results shows that in physical appearance none of the seven originals carrying 100 per cent of typical kernels (Group I) maintained their perfection in their progeny—all showed some starchy kernels. The fact that those grown at Modesto showed 97.5 per cent of typical kernels in their progeny while those grown at Yuba City showed but 60.1 per cent very strongly suggests there must have been some local condition of either soil or climate which influenced this change.

The average protein content of this group at Modesto and Yuba City decreased slightly, as did the percentage of typical kernels, showing 13.15 per cent total protein in the originals and 12.91 per cent in the progeny; while at Yuba City the results were 12.52 per cent for the originals and 11.64 for the progeny. It will be noted also that the Modesto samples possessed somewhat higher total protein as well as a larger percentage of typical kernels than did those grown at Yuba City.

Under Group II at Modesto the progeny showed an average of 92.5 per cent of typical kernels from originals carrying absolutely none, and a comparative protein content of 10.97 per cent for the originals against 13.55 per cent for the progeny, or an increase of 2.58 per cent.

Group III at Modesto carried an average of 40.7 per cent typical kernels in the originals and 96.6 per cent in the progeny, and a protein content of 12.55 and 13.11 respectively, a distinct increase in both respects. At Yuba City this group showed 62.9 and 69.5 per cent typical kernels in the originals and progeny respectively, and a protein content of 12.07 per cent against 11.92 per cent.

Considered as a whole the results are expressed below:

1906	Group I: Number of samples in group	Group I: Per cent typical kernels	Group I: Per cent total protein	Group II: Number of samples in group	Group II: Per cent typical kernels	Group II: Per cent total protein	Group III: Number of samples in group	Group III: Per cent typical kernels
Original	7	100.0	12.74	9	0.0	10.58	6	55.6
Progeny	7	81.5	12.78	9	75.6	12.50	6	78.5

1906	Total number of trials	General average per cent typical kernels	General average per cent total protein
Original	22	47.39	11.71
Progeny	22	78.2	12.54

It is here shown that the average per cent of typical kernels in all the originals was 47.4 and in the progeny 78.2, and the protein content 11.71 per cent and 12.54 per cent respectively. *It is perfectly evident from these figures that a wheat which consists of 100 per cent starchy kernels may, in a single season, revert to practically a perfect wheat, or to essentially the same average protein content for the season and region as a wheat grown from perfectly glutenous kernels.*

Instances of this are particularly shown in samples no. 713 and no. 725. In the first the original consisted of 100 per cent of entirely starchy kernels and still produced 96.9 per cent of typical kernels in the progeny. In the second the same is shown to a somewhat smaller extent, the original carrying but 38.3 per cent typical kernels and still producing 97.9 per cent in the progeny.

Other trials.—Trials were also made to determine the percentage of typical seed in six varieties grown at Modesto from seed in which the percentage of typical kernels had been previously determined, using 1000 kernels as a basis. These were also seeded in rows and were harvested in the hard dough stage. Counts were then made to determine the percentage of typical kernels in the progeny. The results appear below.

Name	Per cent of typical kernels in original 1905	Per cent of typical kernels 1906
Fretes	94.0	95.2
Redwinter	51.0	91.5
Hungarian	78.7	95.3
Kubanka	38.3	72.6
Koola	16.8	93.9
Marouani	43.2	93.1
Average	53.7	90.2

In each of the above cases the percentage of typical kernels increased in the 1906 crop over those of the 1905 crop and the average increase was from 53.7 to 90.2; it seems probable that some climatic or soil factor is more than likely to have been the cause of this change. This is particularly noticeable upon comparing the results between the two stations.

The above figures not only do not indicate that there was any strongly marked tendency toward lowering in quality, but, on the other hand, the general tendency seems to be upward for this season, particularly at Modesto.

The Relation of Moisture.—It has been shown repeatedly by many investigators that the composition of plants varies considerably in different localities and in different seasons, and that the principal factor seems to be the climate instead of the soil, variations due to the latter being very slight if any. This feature will be presented more in detail later in this paper. While the relation of the water content of the soil at various stages of the plant growth to the protein content of wheats also forms a portion of these investigations for later presentation, it may be said that the Utah Station has conducted a number of experiments upon the effect of water upon the composition of plants, the method of which in each case has been to apply different amounts of water throughout the season on contiguous plats of uniform land. The following selected results from the Utah experiments as affecting the protein content of the grain are of interest in this connection.

Inches of water applied	Protein content of Corn kernels	Oat kernels	Wheat kernels
7.5	15.08	20.79	26.72
15.0	13.48	17.29	19.99
37.3	12.52	15.49	16.99

It is shown here that as the amount of water is increased the protein content decreases.

Others have also observed the effect of water upon the composition of crops. Mayer, in Holland, showed that on a soil having 10 per cent of water the crop contained 10.6 per cent of protein, while on a soil with 30 per cent of water the protein percentage was only 6.6. Carleton calls attention to the fact that in the same varieties of wheat grown in the humid and arid regions of the United States the protein content was 11.94 per cent for the former and 14.4 per cent for the latter. Experiments conducted at Rothamstead, England, show that barley in a wet year contained 9.81 per cent of protein and in a dry year 12.99 per cent.

The particular connection of this review of the observation of other workers to the results here presented lies in the differences in the results secured in 1906 between the Modesto and the Yuba City stations, at the former of which both the percentage of typical kernels and the protein content in the progeny was distinctly higher than at the latter. These three factors are contrasted below.

	Inches rainfall Dec. 1-June 30	Per cent typical kernels	Per cent total protein
Modesto	11.94	95.35	13.50
Yuba City	26.68	63.99	11.74

A very casual observation of these results shows that both the distinct difference in percentage of typical kernels and that between the protein content of the grain of the two stations was without doubt very strongly, if not entirely, determined by the difference in moisture which the grain received after planting.

EXPERIMENTS OF 1907

In 1907 the experiment described above was continued at Modesto and Yuba City, and also extended to Tulare. The results are stated below.

MODESTO

Lab. No.	Name	Condition of seed	Date of harvest	Per cent of typical kernels	Number kernels in 10 grams	As analyzed: Moisture	As analyzed: Total nitrogen	As analyzed: Protein	As analyzed: Ash	Calculated to dry basis: Total nitrogen	Calculated to dry basis: Protein	Calculated to dry basis: Ash
645C	Kubanka	Clear	Original	100.0	217	11.10	1.74	9.96	2.04	1.96	11.20	2.21
927A	Kubanka	....	June 21	48.0	222	11.95	1.71	9.74	1.76	1.94	11.06	1.98
928C	Kubanka	Spotted	Original	0.0	221	11.18	1.48	8.37	1.69	1.65	9.42	1.90
928A	Kubanka	....	June 21	49.0	249	11.50	1.70	9.66	1.74	1.91	10.92	......
929C	Kubanka	White	Original	0.0	267	11.92	1.24	7.09	1.58	1.41	8.05	1.96
929A	Kubanka	....	June 21	56.0	242	11.52	1.69	9.61	1.83	1.89	10.87	2.07
926C	Chul	Dark	Original	100.0	232	11.46	1.94	11.06	1.75	2.19	12.48	1.97
926A	Chul	....	June 12	60.0	227	11.61	1.71	9.74	2.04	1.93	11.02	2.31
925C	Chul	Spotted	Original	0.0	223	11.50	1.65	9.45	2.00	1.87	10.67	2.26
925A	Chul	....	June 12	42.0	220	11.93	1.41	8.05	1.83	1.60	9.14	2.07
924C	Chul	Dark	Original	0.0	232	11.57	1.71	10.75	1.81	2.12	12.14	2.04
924A	Chul	....	June 12	49.0	242	11.89	1.52	8.71	1.88	1.73	9.88	2.11
923C	Kharkov	Clear	Original	100.0	......	11.76	2.03	11.56	2.14	2.30	13.10	2.42
923A	Kharkov	....	....	93.0	295	11.80	2.12	12.08	1.96	2.40	13.69	2.22
930C	Fretes	Spotted	Original	83.3	145	11.73	1.69	9.68	2.03	1.92	10.96	2.29
930A	Fretes	....	June 21	85.1	235	11.99						
931C	Erivan	Spotted	Original	80.9	297	11.26	2.06	11.76	1.89	2.32	13.26	2.13
931A	Erivan	....	June 21	76.7	365	11.56	1.61	9.21	1.95	1.83	10.42	......
932C	Gharnovka	Spotted	Original	21.4	263	11.52	1.55	8.82	1.89	1.63	9.28	2.13
932B	Gharnovka	....	June 21	29.5	267	12.07	1.59	9.07	1.68	1.81	10.32	1.91
933C	Koola	Spotted	Original	87.0	188	13.59	1.59	11.54	1.93	2.34	13.36	2.23
933A	Koola	....	June 21	57.1	255	11.88	1.80	10.28	1.91	2.04	11.66	2.16
934C	Kubanka	Spotted	Original	78.0	200	11.47	1.64	9.39	2.00	1.86	10.61	2.26
934A	Kubanka	....	June 21	40.9	225	11.75	1.64	9.34	1.74	1.85	10.59	1.97
935C	Velvet Don	Spotted	Original	44.1	275	11.46	1.58	9.00	1.69	1.71	10.17	1.91
935A	Velvet Don	....	June 21	37.3	280	11.78	1.80	10.28	1.77	2.04	11.65	2.00

TABLE 3.—SHOWING PHYSICAL AND CHEMICAL DEVIATION OF WHEAT KERNELS FROM TYPE SEEDED IN 1907—(*Continued*)

YUBA CITY

Lab. No.	Name	Condition of seed	Date of harvest	Per cent of typical kernels	Number kernels in 10 grams	As analyzed: Moisture	As analyzed: Total nitrogen	As analyzed: Protein	As analyzed: Ash	Calculated to dry basis: Total nitrogen	Calculated to dry basis: Protein	Calculated to dry basis: Ash
645A	Kubanka	Clear	Original	100.0	204	12.53	2.36	13.46	1.80	2.70	15.39	2.06
647	Kubanka	....	July 2	48.6	201	13.24	1.68	9.58	1.71	1.93	11.03	1.97
648S	Kubanka	Spotted	Original	0.0	200	12.71	1.69	9.64	2.04	1.94	11.05	2.33
850	Kubanka	....	July 2	48.3	203	13.08	1.61	9.20	1.67	1.85	10.58	1.92
651W	Kubanka	White	Original	0.0	205	12.79	1.70	9.72	2.16	1.94	11.15	2.48
853	Kubanka	....	July 2	38.9	224	13.50	1.59	9.07	1.98	1.84	10.48	2.29
654	Chul	Dark	Original	100.0	203	10.50	1.81	10.28	1.99	2.02	11.49	2.22
855	Chul	....	June 29	58.1	202	12.98	1.48	8.47	2.01	1.71	9.74	2.31
661	Chul	White	Original	0.0	201	12.96	1.93	10.03	1.89	1.89	11.54	2.17
857	Chul	....	June 29	82.8	200	13.88	1.18	6.73	1.85	1.37	7.81	2.15
338A1	Turkey Red	Clear	Original	0.0	298	10.41	1.77	10.05	1.87	1.97	11.22	2.13
338A5	Turkey Red	....	July 13	75.7	310	11.86	2.86	16.32	1.77	2.81	18.52	2.01
666	Kharkov	Spotted	Original	93.1	301	10.47	2.13	12.10	2.15	2.38	13.52	2.40
859	Kharkov	....	Aug. 17	83.9	310	11.64	1.71	10.75	2.07	2.18	12.44	2.40
669	Weissenberg	Spotted	Original	87.7	304	10.04	2.09	11.88	2.18	2.32	13.32	2.42
862	Weissenberg	....	Aug. 16	89.1	270	13.67	2.43	13.87	3.39	3.39	16.06	2.38
663	Fretes	Spotted	Original	100.0	217	10.10	2.02	11.48	2.10	2.25	12.80	2.34
866	Fretes	....	July 2	83.5	225	12.85	1.72	9.82	2.12	1.94	11.27	2.43
678	Kubanka	Spotted	Original	63.4	215	10.31	1.91	10.84	2.05	2.13	12.12	2.29
869	Kubanka	....	July 8	89.2	184	13.36	3.59	20.48	1.93	4.16	23.64	2.22
684	Velvet Don	Spotted	Original	79.5	217	10.05	2.02	11.98	1.95	2.25	13.74	2.17
870	Velvet Don	....	July 2	90.1	239	12.84	2.13	12.17	2.27	2.45	13.96	2.61
696	Gharnovka	Spotted	Original	6.5	208	11.28	1.55	8.80	2.02	1.74	9.92	2.27
872	Gharnovka	....	July 2	66.6	210	12.06	1.90	10.84	1.74	2.11	12.05	......
874	Beloglina	Spotted	Original	59.9	305	10.50	1.66	9.41	1.95	1.85	9.43	2.21
682	Beloglina	....	July 23	77.4	314	12.72	1.82	10.40	2.22	2.09	11.91	2.54

TABLE 3.—SHOWING PHYSICAL AND CHEMICAL DEVIATION OF WHEAT KERNELS FROM TYPE SEEDED IN 1907—(*Concluded*)

TULARE

Lab. No.	Name	Condition of seed	Date of harvest	Per cent of typical kernels	Number kernels in 10 grams	As analyzed				Calculated to dry basis		
						Moisture	Total nitrogen	Protein	Ash	Total nitrogen	Protein	Ash
681A	Beloglina	Spotted	Original	66.1	268	11.03	1.78	10.11	2.03	1.99	11.36	2.28
892	Beloglina	....	June 21	59.4	271	13.21	1.94	9.51	2.04	1.92	10.96	2.22
684	Velvet Don	Spotted	Original	79.4	217	10.05	2.02	11.98	1.95	2.41	13.74	2.17
894	Velvet Don	....	June 6	93.5	249	13.31	1.42	8.10	1.97	1.64	9.34	2.04
696	Kharnovka	Spotted	Original	6.5	298	11.28	1.55	8.80	2.02	1.74	9.92	2.27
899	Gharnovka	....	June 11	44.1	303	12.07	1.53	8.75	1.97	1.97	10.71	2.24
648	Kubanka	Spotted	Original	50.8	200	12.71	1.69	9.64	2.04	1.94	11.05	2.33
903	Kubanka	....	July 29	20.0	225	13.34	1.61	9.18	1.68	1.87	10.60	1.93
338B2	Turkey Red	Spotted	Original	50.1	289	10.41	1.78	10.11	1.94	1.96	11.28	2.18
902	Turkey Red	....	July 29	66.8	283	14.44	1.75	10.01	1.82	2.05	11.71	2.12
664	Fretes	Typical	Original	100.0	213	10.37	2.06	11.70	2.05	2.29	13.05	2.28
904	Fretes	....	June 3	0.0	220	13.87	1.61	9.17	1.86	1.86	10.60	2.16
676	Kharnovka	Spotted	Original	9.0	228	11.09	1.56	8.86	2.01	1.75	9.95	2.26
900	Kharnovka	....	July 29	46.8	232	12.97	1.76	10.00	2.07	2.11	12.06	2.37

Discussion of 1907 Results.—Essentially the same results are shown here as in the preceding season. Of the seven (7) originals in Group I, all of the progeny dropped distinctly below the original standard, showing 55.99 per cent of typical kernels, while the eight samples in Group II, carrying distinctly starch kernels in the originals, all increased by about the same amount as the others dropped, the average per cent of typical kernels in the progeny being 55.2 per cent, or less than 0.7 per cent below those of Group I.

In the group of typical kernel originals, only one out of seven increased in protein content, the average per cent in the originals being 12.79 against 11.20 per cent in the progeny, or a drop of 1.59 per cent. In Group II, consisting entirely of the distinctly starchy kernels, there was a universal increase in the typical kernels in the progeny, and three out of eight increased in protein content, the averages being 10.65 per cent for the originals and 11.02 per cent for the progeny. Group III showed 58.1 per cent typical kernels in the originals and 64.1 per cent in the progeny, an increase of 6 per cent; and 11.50 and 12.25 per cent total protein, respectively.

Summarizing by groups as in the results of the preceding year, the figures appear as below:

	Group I			Group II			Group III	
1907	Number in group	Per cent typical kernels	Per cent total protein	Number in group	Per cent typical kernels	Per cent total protein	Number in group	Per cent typical kernels
Original	7	100.0	12.79	8	0.0	10.65	18	58.10
Progeny	7	55.9	11.24	8	55.2	11.02	18	64.10

1907	Total number trials	General average per cent typical kernels	General average per cent protein
Original	33	58.1	11.56
Progeny	33	60.2	11.72

Eighteen of these thirty-three samples showed an increase of typical kernels in the progeny over the originals, the respective average being 60.2 and 54.6. The protein content increased in sixteen (16) out of thirty-three cases, with averages for originals and progeny of 11.56 per cent against 11.72 per cent.

EXPERIMENTS OF 1908

The same experiments were continued in 1908 at Davis instead of Yuba City, and at Ceres instead of Modesto. The tabulated results of this season are presented below:

TABLE 4.—SHOWING PHYSICAL AND CHEMICAL DEVIATION OF WHEAT KERNELS FROM TYPE SEEDED IN 1908

DAVIS, 1908

						As analyzed					Calculated to dry basis			
Lab. No.	Name	Condition of seed Per cent typical seed in original	Date of harvest	Per cent typical seed	Number kernels in 10 grams	Moisture	Total nitrogen	Total protein	Gliadin	Ash	Total nitrogen	Total protein	Gliadin	Ash
870	Velvet Don	Spotted	Original	90.1	239	12.84	2.13	12.17	4.12	2.27	2.44	13.96	4.73	2.61
870/08	Velvet Don	....	June 27	100.0	209	12.18	2.13	12.12	1.56	1.69	2.42	13.80	......	......
871	Velvet Don	Spotted	Original	96.1	216	13.17	2.09	11.94	4.53	2.22	2.41	13.75	......	......
871/08	Velvet Don	....	June 29	95.9	222	12.10	2.01	11.46	4.23	1.48	2.25	13.04	......	......
873	Gharnovka	Spotted	Original	76.5	206	13.70	1.90	10.83	2.68	2.14	2.20	12.55	......	......
873/08	Gharnovka	....	June 28	100.0	181	12.15	2.05	11.76	2.02	1.52	2.35	13.38	......	......
909B	Jegar	Clear	Original	100.0	......	10.36	2.44	13.92	4.88	2.20	2.72	15.53	......	......
909/08	Jegar	....	July 8	96.9	272	11.69	2.23	12.73	3.18	1.83	2.53	14.42	......	......
910	Bachier	Clear	Original	100.0	......	9.79	2.42	13.81	......	......	2.52	15.31	......	......
910/08	Bachier	....	June 27	96.2	167	12.89	1.98	11.33	1.06	1.68	2.29	13.06	......	......
922	Arnautka	Clear	Original	100.0	......	9.43	1.41	8.07	......	......	1.56	8.91	......	......
922/08	Arnautka	....	June 30	97.8	201	10.96	......	13.00	3.69	1.39	2.75	15.72	......	......
911	Hybrid	Clear	Original	100.0	......	9.54	2.28	14.11	3.10	1.95	2.73	15.59	......	......
911/08	Hybrid	....	July 11	100.0	302	13.34	2.08	11.88	3.61	1.79	2.40	13.71	......	......
917	Hybrid	Clear	Original	100.0	......	9.14	2.02	11.52	2.65	1.99	2.22	13.67	......	......
917/08	Hybrid	....	July 10	100.0	345	13.59	2.61	14.85	5.73	1.87	3.03	17.30	......	......
919	Hybrid	Clear	Original	100.0	......	8.54	1.94	11.08	5.04	1.96	2.33	13.21	......	......

TABLE 4.—SHOWING PHYSICAL AND CHEMICAL DEVIATION OF WHEAT KERNELS FROM TYPE SEEDED IN 1908—(*Continued*)

Lab. No.	Name	Condition of seed Per cent typical seed in original	Date of harvest	Per cent typical seed	Number kernels in 10 grams	As analyzed					Calculated to dry basis			
						Moisture	Total nitrogen	Total protein	Gliadin	Ash	Total nitrogen	Total protein	Gliadin	Ash
919/08	Hybrid	....	July 16	100.0	377	12.74	2.27	12.98	5.13	1.76	2.61	14.87	......	......
851	Kubanka	Spotted	Original	42.8	210	13.09	1.75	10.00	3.09	1.62	2.02	11.51	3.55	1.87
851/08	Kubanka	....	June 27	88.4	......	11.35	1.99	11.33	3.41	1.54	2.24	12.78	......	......
338B5	Turkey	Spotted	Original	74.0	313	11.16	1.94	11.11	3.77	1.77	2.19	12.50	4.24	1.99
338B5/08	Turkey	....	July 16	100.0	......	12.14	2.38	13.52	4.78	1.83	2.69	15.36	......	......
745B	Kubanka	Spotted	Original	66.2	......	13.57	1.58	9.01	3.43	1.80	2.69	10.42	......	......
745B/08	Kubanka	....	July 5	100.0	215	12.13	2.39	13.82	4.09	1.77	2.76	15.73	......	......
872	Gharnovka	Spotted	Original	66.6	210	12.06	1.90	10.84	3.08	1.74	2.22	12.65	3.50	......
872/08	Gharnovka	....	July 1	98.4	215	12.93	2.42	13.81	4.16	1.75	2.76	15.72	......	......
962	Fife	Clear	Original	100.0	315	8.64	1.96	11.18	......	......	2.15	12.23	......	......
962/08	Fife	....	July 7	100.0	319	12.15	2.61	14.88	5.13	1.72	2.97	16.94	......	......
868	Kubanka	Spotted	Original	89.18	184	13.36	3.59	20.48	4.05	1.93	4.15	23.64	4.67	2.22
868/08	Kubanka	....	July 2	99.70	192	13.99	2.42	13.79	4.28	1.58	2.79	15.91	......	......
847	Kubanka	Spotted	Original	48.6	......	13.24	1.68	9.58	3.37	1.71	1.93	11.04	......	......
847/08	Kubanka	....	July 1	98.5	201	13.81	2.19	12.47	4.00	1.56	2.53	14.46	......	......
870	Velvet Don	Spotted	Original	90.1	239	12.84	2.13	12.17	4.12	2.27	2.44	13.96	......	......
870/08	Velvet Don	....	July 2	99.1	214	13.36	2.31	13.17	4.52	1.54	2.66	15.20	......	......

Summarizing the results of the foregoing table for the three groups we find the following:

1908	Group I: Number in group	Group I: Per cent typical kernels	Group I: Per cent total protein	Group II: Number in group	Group II: Per cent typical kernels	Group II: Per cent total protein	Group III: Number in group	Group III: Per cent typical kernels
Original	7	100.0	13.44	None of this type			10	72.23
Progeny	7	98.7	15.14	seeded			10	97.80

1908	Total number trials	General average per cent typical kernels	General average per cent protein
Original	17	83.6	13.54
Progeny	17	98.1	14.78

Discussion of 1908 Results.—Out of a total of seventeen cases twelve show both an increased number of typical kernels and an increased protein content in the progeny over the originals, the averages being as follows:

	Original	Progeny
Average per cent typical kernels	83.6	98.10
Average per cent total protein	13.54	14.78

In Group I, three, out of a total of seven, show a decrease in the percentage of typical kernels and the other four show the same as the original, the average being 98.7 per cent with an average protein content of 13.49 per cent in the original against 15.14 in the progeny.

In Group III, consisting of ten samples, nine show an increase in both percentage of typical kernels and total protein, the average being:

	Original	Progeny
Average per cent typical samples	72.23	97.80
Average per cent total protein	13.59	14.54

The results expressed by groups are shown in the following table:

	Number of trials	Per cent of typical kernels: Original	Per cent of typical kernels: Progeny	Per cent total protein: Original	Per cent total protein: Progeny
Group I	21	100.0	78.7	13.00	13.04
Group II	17	0.0	65.4	10.61	11.76
Group III	34	61.97	80.1	12.44	13.03

GENERAL DISCUSSION AND CONCLUSION

Reviewing the results of the three years, the general average of typical kernels in the original was 63.63 per cent and of the seed produced therefrom 77.99 per cent, while the protein content was 12.34 per cent and 12.95 per cent respectively.

The results as a whole show:

First—That in general the physical appearance of durum and red wheats is a fair indication of their relative protein content; kernels having a distinctly horny or glutenous appearance being higher in protein than those of a more or less dull or starchy appearance.

Second—That there is a wide seasonal fluctuation in protein content of wheat which may become so great as to overbalance almost entirely any hereditary tendency of starchy originals to produce the same characteristics in their progeny.

Third—That the protein content of wheat in a locality is undoubtedly largely dependent upon the seasonal precipitation in such locality.

Fourth—That the use of perfectly typical glutenous seed is invariably followed under California conditions by a lowering of the gluten content, as indicated both by the physical appearance of the grain and by its protein content.

Fifth—That if the original carries a considerable percentage of starchy kernels the progeny usually shows an increase toward the typical character to a degree determined by the character of the season in the locality. This is especially so with reference to the precipitation, which is in some instances may have such a strong influence as to cause a practically perfect grain to result from an original seed carrying 100 per cent of starchy kernels.

Sixth—The last tabulation by groups further indicates quite strongly, however, that as a matter of fact the character of the seed used has quite a marked influence upon the progeny, and that the quality of the seed used, to some degree at least, determines the character of the resultant crop, for it will be noted that as the originals decrease in both percentage of typical kernels and protein the progeny in each case decrease in the same order, although the effect of this is materially lessened and sometimes

almost entirely overcome by the character of the season, as shown by the other results.

THE RELATION OF THE TIME OF PLANTING TO THE PROTEIN CONTENT OF WHEAT KERNELS

On account of certain differences in the physical appearance of kernels from early and late planted wheats in preceding seasons, experiments were conducted in 1908 to ascertain more definitely the relation of early and late planting to the protein content of wheat kernels. In these experiments it was intended to conduct parallel series of plantings at the University Farm, Davis, and at the substation at Tulare. At the former place, however, conditions were not favorable for early seeding, and all had to be planted too late to be at all satisfactory in presenting any decided contrast in planting time, particularly for the winter wheats, there being but fifteen days between the early and late seeding. The first plantings of the season were not made until February 27, and the second plantings on March 13. At Tulare there was a wider difference, the plantings having been made on December 12, and January 17.

As a matter of record, however, the analyses of these grains are presented below:

TABLE 5.—SHOWING THE RELATION OF TIME OF PLANTING TO THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF WHEAT KERNELS

DAVIS, 1908

	First planting				Second planting			
Lab. No.	Typical kernels Per cent	Total protein Per cent	Gliadin Per cent	Ash Per cent	Typical kernels Per cent	Total protein Per cent	Gliadin Per cent	Ash Per cent
2/05	100.0	11.81	1.41	1.76	67.1	10.67	2.40	2.04
847A	68.3	11.19	1.61	1.76	40.6	10.62	2.19	2.03
870A	100.0	13.78	1.80	1.73	100.0	13.74	3.12	1.72
873A	100.0	13.38	2.32	1.73	84.0	13.08	3.17	1.72
909A	96.9	14.41	3.60	2.07	97.7	14.89	4.99	1.49
910A	96.2	12.99	6.88	1.93	60.2	9.77	1.80	2.03
911D	95.6	13.71	4.16	2.06	99.4	18.26	8.05	2.37
917D	100.0	17.25	6.95	2.16	100.0	19.68	5.41	2.08
919C	85.7	14.87	5.88	2.01	99.4	17.27	5.82	2.22
922A	99.0	14.58	4.15	2.00	99.1	12.07	3.09	2.10
595	95.3	14.91	5.90	1.89	93.3	13.24	5.53	2.13
Av.	94.2	13.88	4.06	1.92	85.5	13.94	4.14	1.99

TULARE, 1908

	First planting				Second planting			
Lab. No.	Typical kernels Per cent	Total protein Per cent	Gliadin Per cent	Ash Per cent	Typical kernels Per cent	Total protein Per cent	Gliadin Per cent	Ash Per cent
901	....	10.34	3.58	......	....	11.30	4.75	......
896	14.3	9.82	3.09	1.92	85.1	12.95	4.32	1.68
870	20.7	9.94	3.43	1.88	68.1	12.15	4.97	1.87
848	30.8	10.96	3.67	2.03	60.1	11.53	4.04	1.84
892	74.5	11.41	3.51	2.04	98.1	13.63	4.48	2.04
338A6	78.3	11.47	3.60	1.92	97.4	13.52	4.44	2.08
Av.	43.7	10.65	3.48	1.96	81.7	12.51	4.50	1.90
Grand av.	68.9	12.26	3.77	1.94	83.6	13.22	4.32	1.95

For the reason indicated above the plantings made at Davis should not be regarded as having much bearing upon the question. Considering the plantings made at Tulare, however, it will be noted that in every case the late plantings showed both a higher percentage of typical kernels and a higher protein and gliadin content than the early plantings.

The average in the case of the Tulare samples was:

	Number of trials	Per cent typical kernels	Per cent total protein	Per cent gliadin
Early plantings	5	43.7	10.65	2.48
Late plantings	5	81.7	12.51	4.50

Further trials were made during the season of 1909–10 at Davis and Tulare. The planting dates at these stations were as follows:

	Early	Late
Davis	February 27th	March 13th
Tulare	December 26th	January 25th

TABLE 6 SHOWING THE RELATION OF TIME OF PLANTING TO THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF WHEAT KERNELS

DAVIS, 1909

	First planting				Second planting			
Lab. No.	Typical kernels Per cent	Total protein Per cent	Gliadin Per cent	Ash Per cent	Typical kernels Per cent	Total protein Per cent	Gliadin Per cent	Ash Per cent
870B	98.5	15.77	5.77	1.75	99.1	15.46	6.16	1.90
873B	94.8	16.14	6.00	1.82	97.8	15.86	6.49	1.88
847C	99.0	15.46	6.05	1.73	98.0	16.01	6.52	2.13
909B	55.0	17.62	8.16	1.99	58.2	18.02	7.87	2.75
910B	97.9	16.66	6.20	1.79	100.0	16.82	5.94	1.98
922B	99.0	18.34	8.01	1.80	99.1	18.42	5.68	1.89
917E	98.0	18.42	8.35	2.21	100.0	20.02	7.44	2.45
388a5	100.0	18.18	7.71	2.17	100.0	18.58	6.92	2.28
875B	100.0	18.42	8.18	2.02	100.0	19.20	8.20	2.39
911E	....	16.82	8.11	1.79	....	19.44	9.14	2.12
912D	100.0	20.00	8.88	2.28	100.0	18.66	6.39	2.48
914D	98.0	17.62	7.86	2.03	100.0	17.62	7.91	2.45
Av.	94.5	17.45	7.44	1.94	95.6	17.84	7.05	2.22

TABLE 6—(*Continued*)

TULARE, 1909

	First planting				Second planting			
Lab. No.	Typical kernels Per cent	Total protein Per cent	Gliadin Per cent	Ash Per cent	Typical kernels Per cent	Total protein Per cent	Gliadin Per cent	Ash Per cent
1043aG	77.0	10.73	3.45	2.23	100.0	17.26	6.31	2.86
1040aG	48.0	11.13	3.75	2.24	100.0	17.21	5.50	2.20
1041aG	44.0	11.07	3.79	2.14	99.0	15.90	5.35	2.40
1042aG	89.1	13.12	4.99	......	....	18.91	6.65	2.59
1040aS	35.0	11.36	4.11	2.29	100.0	13.73	5.91	2.22
1041aS	66.0	10.50	3.68	2.10	100.0	10.33	......	2.34
1042aS	100.0	12.89	5.06	2.06	....	16.47	6.19	2.54
1043aS	53.6	10.62	3.96	2.37	100.0	16.47	......	2.74
1151	99.6	15.38	7.32	......	99.2	15.34	6.50	......
1155	100.0	17.20	6.95	1.81	100.0	17.24	5.38	2.25
Av.	71.2	12.40	4.71	2.15	99.8	15.88	5.97	2.46
Grand av.	82.8	14.92	6.07	2.04	97.7	16.86	6.51	2.34

These results show that out of twenty-two (22) cases, seventeen (17) carried a higher protein content in the later plantings than in those planted early and that a like number out of the twenty-two carried either a larger percentage or an equal number of typical kernels in the late plantings.

The averages are shown below:

	Trials	Typical kernels	Total protein	Gliadin
Early plantings	22	82.8	14.92	6.07
Late plantings	22	97.7	16.86	6.51

To further secure data upon the effect of the time of planting upon the quality of the grain, twelve (12) varieties of wheat were seeded at Ceres on four different dates, in rows 16½ feet long and 12 inches apart, as follows:

First planting	November 28, 1908
Second planting	December 12, 1908
Third planting	December 31, 1908
Fourth planting	January 19, 1909

The grain made a good stand and grew well during the season and matured as shown in the following table:

DATE OF RIPENING

Lab. No.	Date of plantings			
	Nov. 28	Dec. 12	Dec. 31	Jan. 19
914	June 15	June 18	June 22	July 17
909	June 14	June 18	June 20	July 7
910	June 18	June 20	June 20	June 24
911	June 16	June 20	June 26	July 7
915	June 20	June 24	July 3	July 7
913	June 16	June 20	June 24	July 7
917	June 15	June 16	June 19	July 7
916	June 11	June 18	June 22	July 7
919	June 16	June 20	June 24	July 7
912	June 16	June 18	June 22	July 7
1895	June 18	June 20	June 22	June 24
2/05	June 15	June 15	June 15	June 15

This series of plantings is of special interest in that out of the twelve varieties planted all but one show the highest protein content in the latest planting, and the one exception shows the highest in the third planting. In this case the difference between the protein content of the third and fourth plantings is less than one-half of 1 per cent. It is further of interest to note that there was quite a regular increase in the protein content in the order of planting. While the season was evidently one conducive to the development of a relatively high quality of grain

generally, it is noticeable that the average percentage of typical kernels also follows the same order as the protein content, although the difference is slight. If the average be made after discarding the last sample, which constitutes the single exception above referred to, the order in the average of typical kernels will appear absolutely the same as that of the protein content, and very consistently bears out the results secured at Davis and Tulare, previously discussed. While it may reduce the yield, ***relatively late seeding tends to produce a grain of better quality than does early planting.***

This same fact is further evidenced by a series of thirty-seven (37) types of New South Wales hybrid stocks seeded at Davis in the season of 1910–11; the dates of planting being December 12, 1910, and February 20, 1911. The analyses from this lot are tabulated below:

TABLE 7.—SHOWING THE RELATION OF THE TIME OF PLANTING TO THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF WHEAT KERNELS

CERES, 1909

Lab. No.	First planting				Second planting				Third planting				Fourth planting			
	Typical kernels Per cent	Total protein Per cent	Gliadin Per cent	Ash Per cent	Typical kernels Per cent	Total protein Per cent	Gliadin Per cent	Ash Per cent	Typical kernels Per cent	Total protein Per cent	Gliadin Per cent	Ash Per cent	Typical kernels Per cent	Total protein Per cent	Gliadin Per cent	Ash Per cent
914	98.0	15.96	6.70	1.97	100.0	16.98	6.87	1.90	100.0	16.81	6.86	2.05	100.0	17.27	7.13	2.32
909	100.0	15.73	7.21	1.80	100.0	16.70	7.78	2.15	100.0	17.15	7.55	2.17	100.0	17.89	7.38	2.12
910	100.0	13.74	4.09	1.97	100.0	14.54	4.77	1.91	99.0	16.30	5.27	2.00	97.0	16.76	4.78	2.00
911	97.0	14.54	5.27	1.81	98.0	16.30	6.45	1.87	100.0	16.87	6.46	2.11	100.0	17.49	5.88	1.85
915	100.0	16.36	5.22	2.00	100.0	16.64	5.05	1.98	100.0	17.21	6.15	2.08	100.0	17.72	6.01	2.28
913	100.0	17.38	6.86	1.79	100.0	17.89	6.83	1.89	100.0	18.29	6.56	1.99	100.0	19.06	6.57	2.15
917	97.0	15.85	5.22	1.87	99.0	16.19	5.58	1.88	100.0	16.53	6.07	1.94	100.0	18.40	5.83	2.06
916	100.0	17.04	6.07	1.85	100.0	17.61	6.37	1.89	100.0	17.44	6.13	2.08	100.0	19.03	6.65	2.28
919	98.0	16.70	5.28	1.95	99.0	15.56	5.63	1.62	100.0	15.28	5.19	1.74	100.0	18.35	5.82	2.02
912	85.0	17.72	6.37	1.90	100.0	18.40	6.82	2.01	100.0	18.35	6.95	2.11	100.0	18.63	6.42	2.27
1595	100.0	16.13	5.21	2.14	100.0	16.13	5.29	2.23	100.0	16.59	5.39	2.16	100.0	17.10	5.32	2.20
2/05	94.0	17.27	4.54	2.15	98.0	17.72	5.80	2.10	98.0	18.52	5.70	2.10	97.0	18.12	5.99	2.12
Av.	97.3	16.20	5.67	1.93	99.5	16.72	6.10	1.95	99.8	17.11	6.19	2.04	99.5	17.99	6.15	2.14

TABLE 8 SHOWING THE RELATION OF TIME OF PLANTING TO THE GLUTEN CONTENT OF WHEAT KERNELS

	Early planting			Late planting		
Sample No.	Total gluten	Total gliadin	Ash	Total gluten	Total gliadin	Ash
1	14.37	5.890	1.71	16.41	6.742	1.88
2–1	13.00	5.322	1.71	13.42	5.787	1.78
3	13.74	5.552	1.70	14.54	5.839	2.05
4–B	14.42	5.657	1.73	15.22	6.049	1.76
4–C	12.66	5.555	1.63	15.44	6.503	1.69
4–D	12.15	4.572	1.48	15.22	5.594	1.86
4–E	10.79	4.646	1.82	13.46	6.299	1.96
5–2	11.98	4.311	1.78	15.28	5.248	1.73
5–4	12.55	4.186	1.81	16.41	6.477	1.61
5–5	12.38	4.657	1.88	15.22	5.935	1.61
6	11.26	4.287	1.91	16.30	5.873	1.94
7	13.80	5.424	1.94	17.38	6.844	1.83
8	14.42	6.179	1.74	16.24	7.242	1.60
10–1	13.46	4.595	1.77	16.01	5.600	1.70
10–2	12.21	3.765	1.78	15.33	4.975	1.71
10–3	13.06	4.333	1.61	15.50	5.731	1.73
10–4	11.92	3.845	1.75	16.01	5.560	1.81
11	12.62	5.210	1.74	14.94	6.117	1.97
12–2	14.25	5.339	1.76	14.59	5.765	1.79
12–4	13.06	4.731	1.70	14.93	5.288	1.51
13	13.57	4.884	1.70	14.94	5.310	1.77
15	13.34	4.879	1.81	14.14	5.026	1.95
18	14.02	4.311	1.64	16.13	5.469	1.63
20	13.51	5.418	1.72	15.56	6.162	1.60
21	11.70	4.544	1.56	15.05	5.077	1.63
22	13.17	4.328	1.81	16.41	5.452	1.58
23	16.01	5.707	2.05	17.89	6.747	2.08
24	13.17	4.708	2.15	15.44	5.384	1.80
25	14.08	4.288	2.10	15.79	5.305	1.92
26	13.34	4.461	1.82	15.84	5.163	2.04
27	14.08	4.345	1.87	17.60	6.088	1.98
28	14.76	5.117	1.63	15.39	5.350	1.78
29	11.47	3.311	1.87	14.54	4.146	1.76
30	13.24	5.293	1.65	14.82	5.867	1.70
31	13.57	5.572	1.50	14.54	5.992	1.94
32	13.26	5.305	1.58	14.37	6.054	1.64
33	12.49	4.515	1.87	14.54	6.418	1.81
Av.	13.158	4.812	1.764	15.428	5.796	1.787

In this series of plantings, without a single exception, the late planted samples run higher in protein than those planted early, and the same holds true of their gliadin content.

General Discussion

Collecting all results for the season of 1908, 1909, and 1911, the following grand averages appear upon which to base conclusions:

		First planting			Second planting		
Year	No. trials	Per cent typical kernels	Per cent total protein	Per cent gliadin	Per cent typical kernels	Per cent total protein	Per cent gliadin
1908	17	78.5	12.75	3.84	84.3	13.45	4.26
1909	34	87.9	15.66	5.92	98.4	16.95	6.39
1911	37	......	13.16	4.84	......	15.43	5.80
Av.	88	83.2	13.85	4.87	91.3	15.28	5.48

These figures show quite definitely that late planting tends toward the production of a grain carrying a higher percentage of total protein and gliadin, as well as a higher percentage of typical kernels, than does early planting. Of the eighty-eight trials made, if we except those at Davis the first season when the two plantings were made at dates too close together for distinctive results, there is a great unanimity of results in favor of the late seeded grain in the respects indicated. Considered as a whole, the late plantings show an increase over the early plantings of 8.1 per cent of typical kernels, 1.43 per cent of protein and .61 per cent of gliadin. Of particular note are the four successive plantings made at Ceres in 1909, in which there is a regular increase in protein, gliadin, and typical kernels from the early to the latest plantings, and also the plantings at Davis in 1910–11 in which the same unanimity in respect to protein and gliadin is shown.

The results covering this season are so uniformly in favor of the late planting as developing the higher protein and gliadin content that the question seems to be very decisively answered.

THE EFFECT OF THE TIME OF HARVESTING UPON THE PROTEIN CONTENTS OF WHEATS

In most parts of the country from which is obtained the recognized high gluten wheat the grain is cut when in the hard dough stage by means of a self-binder and later threshed by means of a stationary threshing outfit. In California practically

all of the grain is left standing on the straw in the field until it is "dead ripe" and finally cut in that condition and threshed in a single operation by means of a combined harvester.

In the later method the grain often stands on the straw and is subjected to the action of the sun for several weeks after reaching the hard dough stage. This difference in the method of harvesting has led to the belief among many that the time of cutting might be one of the causes of the relatively low protein (gluten) content of Pacific Coast wheats.

With the idea of determining the effect of such standing in the field, a series of experiments was planned to ascertain what might be the influence of this practice.

For the purposes of this experiment several varieties of wheat whose kernels possessed distinctive characteristics as indicated in the preceding discussion were hand-separated into three groups as previously shown (page 69). These were drill-seeded under uniform soil and climatic condition at the several stations. One-half of each lot was harvested in the hard dough stage, in which condition it would normally be cut by a binder, and the other half was left standing on the straw in the field until it reached a condition suitable to be cut with a combined harvester. This was finally harvested and each portion subjected to analysis in addition to determining the percentage of typical kernels as indicated by the physical appearance of the kernels, using 1000 kernels as a basis.

Aside from the main question as to the effect of the time of cutting upon the quality of the grain, the data as presented in tabular form further furnishes a means for comparing the original used, with the progeny as in the previously discussed experiment (pages 69–74).

Lab. No.	Name	Per cent typical seed in original	Date of harvest	typical seed in progeny 1906	Number kernels in 10 grams	As analyzed				Calculated to dry basis		
						Moisture	Total nitrogen	Total protein	Ash	Total nitrogen	Total protein	Ash
709	Kubanka	100.0	June 27	97.7	252	10.98	2.33	13.24	1.99	2.62	14.91	2.24
710	Kubanka	100.0	July 31	88.7	204	10.95	2.10	11.96	1.90	2.36	13.40	2.13
711	Kubanka	0.0	June 27	89.4	216	10.87	2.31	13.16	1.98	2.59	14.75	2.22
712	Kubanka	0.0	July 31	69.7	195	10.90	1.98	11.24	1.94	2.22	12.60	2.18
713	Kubanka	0.0	June 27	96.9	195	10.95	2.23	12.68	1.89	2.50	14.20	2.12
714	Kubanka	0.0	July 31	100.0	185	10.63	2.37	13.48	1.90	2.65	15.10	2.13
715	Chul	100.0	June 12	94.1	219	11.96	1.82	10.36	2.00	2.07	11.76	2.27
716	Chul	100.0	July 31	83.4	......	10.10	1.63	9.25	1.84	1.81	10.27	2.05
717	Chul	0.0	June 12	91.6	218	11.13	1.96	11.16	2.00	2.21	12.56	2.25
718	Chul	0.0	July 31	96.0	195	11.09	2.15	12.20	1.95	2.42	13.76	2.19
719	Chul	0.0	June 12	96.1	219	11.23	1.91	10.92	1.90	2.15	12.20	2.14
720	Chul	0.0	July 31	96.3	185	9.20	1.99	11.32	1.87	1.92	12.44	2.06
338A3	Turkey Red	100.0	June 27	98.0	314	11.28	2.08	11.80	2.08	2.34	13.32	2.34
338A4	Turkey Red	100.0	July 31	86.4	320	11.67	1.98	11.24	2.05	2.24	12.76	2.32
338B3	Turkey Red	0.0	June 27	91.1	309	11.19	1.98	11.24	2.02	2.23	12.64	2.27
338B4	Turkey Red	0.0	July 31	90.0	373	10.92	2.10	11.96	2.08	2.36	13.42	2.33
733	Turkey Red	100.0	June 27	99.3	306	10.33	2.16	12.28	2.02	2.40	13.63	2.25
734	Turkey Red	100.0	July 31	92.0	324	10.84	1.99	11.32	1.85	2.11	11.96	2.06
721	Fretes	94.0	June 23	95.2	220	11.57	2.23	12.68	2.13	2.52	14.26	2.41
722	Fretes	94.0	July 31	93.0	220	11.65	2.22	12.60	2.17	2.51	14.26	2.46
723	Koola	16.8	June 21	93.9	200	12.18	2.08	11.80	2.00	2.37	13.40	2.28
724	Koola	16.8	July 31	87.5	199	12.28	2.19	12.44	2.02	2.50	14.10	2.30
725	Kubanka	38.2	June 21	97.9	246	11.01	1.96	11.16	1.88	2.20	12.51	2.11
726	Kubanka	38.3	July 31	87.7	245	11.13	2.12	12.04	1.96	2.23	12.59	2.21
727	Marouani	43.2	July 14	93.1	171	11.50	2.15	12.20	1.98	2.43	13.71	2.28
728	Marouani	43.2	July 31	96.0	174	11.67	2.30	13.08	2.05	2.60	14.72	2.30
729	Red Winter	51.0	June 21	91.5	293	11.32	2.12	12.04	2.05	2.39	13.55	2.31
730	Red Winter	51.0	July 31	88.0	276	11.43	1.88	10.68	2.06	2.12	12.04	2.32
731	....	78.7	June 27	93.5	263	11.21	2.10	11.96	2.03	2.37	13.40	2.28
732	....	78.7	July 31	97.0	297	11.04	2.29	13.00	2.06	2.56	14.51	2.30

TABLE 9. SHOWING PHYSICAL AND CHEMICAL DEVIATION FROM TYPE IN EARLY AND LATE CUT WHEAT—(*Concluded*)

YUBA CITY

Lab. No.	Name	Per cent typical seed in original	Date of harvest	Per cent typical seed in progeny 1906	Number kernels in 10 grams	As analyzed: Moisture	As analyzed: Total nitrogen	As analyzed: Total protein	As analyzed: Ash	Calculated to dry basis: Total nitrogen	Calculated to dry basis: Total protein	Calculated to dry basis: Ash
645	Kubanka	100.0	July 2	55.6	217	10.11	1.92	10.92	2.04	2.14	12.12	2.26
646	Kubanka	100.0	Aug. 13	52.1	199	10.26	1.83	10.36	2.08	2.03	11.56	2.32
648	Kubanka	0.0	July 2	50.8	197	10.38	1.82	10.36	1.98	2.03	11.56	2.21
649	Kubanka	0.0	Aug. 13	44.1	187	10.31	1.78	10.11	1.95	1.99	11.32	2.19
651	Kubanka	0.0	July 2	63.5	205	10.30	1.89	10.76	2.02	2.11	12.04	2.25
652	Kubanka	0.0	Aug. 13	61.7	200	10.28	1.88	10.68	2.06	2.09	11.88	2.29
654	Chul	100.0	June 30	69.4	203	10.50	1.81	10.27	1.99	2.03	11.56	2.22
655	Chul	100.0	Aug. 13	63.0	195	10.67	1.81	10.27	1.98	2.02	11.48	2.22
657	Chul	0.0	June 30	76.8	221	10.31	1.94	11.00	2.00	2.17	12.36	2.12
658	Chul	0.0	Aug. 13	65.1	218	10.65	1.78	10.11	1.88	1.99	11.32	2.10
660	Chul	0.0	June 30	52.0	......	12.49	1.87	10.64	2.00	2.12	12.04	2.28
661	Chul	0.0	Aug. 13	62.3	......	12.43	1.82	10.36	1.94	2.06	11.72	2.22
338A	Turkey Red	100.0	July 7	65.3	300	10.41	1.77	10.03	1.87	1.98	11.25	2.09
338A1	Turkey Red	100.0	Aug. 13	69.6	298	10.40	1.78	10.11	1.91	1.98	11.25	2.13
338B	Turkey Red	0.0	July 7	67.3	300	10.15	1.77	10.03	1.97	1.97	11.20	2.19
338B1	Turkey Red	0.0	Aug. 13	50.1	302	10.41	1.78	11.11	1.94	1.98	11.52	2.17
663	Fretes	50.8	June 30	100.0	217	10.10	2.02	11.48	2.10	2.25	12.80	2.34
664	Fretes	50.8	Aug. 13	100.0	213	10.37	2.06	11.72	2.05	2.30	12.68	2.29
666	Kharkov	37.5	July 10	93.1	301	10.47	2.13	12.12	2.15	2.38	13.68	2.40
667	Kharkov	37.5	Aug. 13	88.7	278	10.46	2.08	11.80	2.08	2.32	13.32	2.23
669	Weissenberg	15.8	July 10	87.7	304	10.04	2.09	11.88	2.18	2.32	13.32	2.42
670	Weissenberg	15.8	Aug. 13	79.1	300	10.10	2.95	11.04	2.17	2.16	13.26	2.41
672	Kahla	75.2	July 2	53.0	201	10.04	2.07	11.76	2.19	2.30	12.68	2.43
673	Kahla	75.2	Aug. 13	79.1	197	10.09	2.62	12.84	2.22	2.52	14.31	2.47
675	Gharnovka	......	July 5	15.3	240	11.28	1.55	8.80	2.02	1.75	9.94	2.78
676	Gharnovka	......	Aug. 13	9.0	235	11.09	1.53	8.70	2.01	1.72	9.77	2.26
678	Kubanka	23.7	July 2	63.4	215	10.31	1.91	10.84	2.05	2.13	12.12	2.29
679	Kubanka	23.7	Aug. 13	71.8	180	10.57	2.13	12.12	2.20	2.38	13.68	2.46
681	Beloglina	......	July 5	66.1	305	10.50	1.66	9.41	1.98	1.85	9.43	2.21
[illegible]	[illegible]	[illegible]	Aug. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Discussion of 1906 Results.—In these results the same thing is noticeable as in the former series, viz., that the samples grown at Modesto as a whole maintained both a higher percentage of typical kernels and a higher protein content than those grown at Yuba City, the comparison by averages being as follows:

	Modesto	Yuba City
Average per cent typical kernels	89.70	65.2
Average per cent protein	11.87	10.5

It is particularly noticeable that, outside of the instances in which the originals carried 100 per cent of typical kernels, there was in this season a practically universal marked increase in the number of typical kernels in the progeny; that in the case of sample no. 714, which carried no typical kernels, the original seed being 100 per cent starchy, the second cutting produced 100 per cent of typical kernels and the first cutting (no. 713) 96.9 per cent of such kernels. Almost as good a showing also is made by samples nos. 719 and 720, which produced respectively 96.1 and 96.3 typical kernels from entirely starchy kernels.

It is further shown that in the case of the early cutting twenty-one out of the thirty-one trials showed an increase in the percentage of typical kernels in the progeny over the original, the relation in those cases in which increase occurred being 42.5 per cent in the original and 83.19 per cent in the progeny, while in the eight cases in which decrease occurred the averages were 96.1 per cent typical kernels in the originals against 75.3 per cent in the progeny, which is entirely confirmatory of the results presented in Table 2.

Looking more particularly at the specific question involved in this experiment, viz., the effect of the time of cutting upon the percentage of typical kernels and the protein content, it is found that the following averages hold:

MODESTO

	Number of trials	Per cent typical kernels	Per cent protein
Early cutting	15	94.6	13.38
Late cutting	15	90.1	13.19

YUBA CITY

	Number of trials	Per cent typical kernels	Per cent protein
Early cutting	16	66.1	11.98
Late cutting	16	64.6	12.05

These average figures show, in the case of the Yuba City lot, an apparent contradiction in that the early cutting with 66.1 per cent typical kernels showed 11.98 per cent protein, while the late cutting with but 64.6 typical kernels showed 12.05 per cent protein. When it is remembered, however, that the difference in the two cuttings is represented by but a single kernel in one hundred and that the average protein content is but seven-hundredths of 1 per cent, it will be seen that the discrepancy is only apparent, and well within the limits of error in either count or analysis.

As a whole, it is shown that out of the total of 31 cases 11 showed an increase of typical kernels in the late cut grain and 14 showed an increased protein content, with the following relative averages:

	Number of trials	Per cent typical kernels	Per cent protein
Early cuttings	31	79.89	12.66
Late cuttings	31	76.9	12.60

The results for 1906 do not show that there is any marked difference to be attributed to allowing the grain to become thoroughly ripe on the straw, as is generally done in California.

EXPERIMENTS OF 1907

The experiments as to the effect of the time of cutting wheat upon its protein content were continued in the manner described above in the season of 1907 at Modesto, Yuba City, and Tulare, with the following results:

TABLE 10. SHOWING PHYSICAL AND CHEMICAL DEVIATION FROM TYPE IN EARLY AND LATE HARVESTED WHEATS

MODESTO, 1907

Lab. No.	Name	Per cent typical seed in original	Date of harvest	Per cent typical seed in progeny	Number kernels in 10 grams	As analyzed: Moisture	As analyzed: Total nitrogen	As analyzed: Total protein	As analyzed: Gliadin	As analyzed: Ash	Calculated to dry basis: Total nitrogen	Calculated to dry basis: Total protein	Calculated to dry basis: Gliadin	Calculated to dry basis: Ash
924A	Chul	100.0	June 10	49.0	242	11.89	1.53	8.71	2.50	1.88	1.74	9.88	2.81	2.13
924B	Chul	100.0	July 20	55.0	221	12.02	1.47	8.38	2.66	1.94	1.75	9.96	3.02	2.20
925A	Chul	0.0	June 10	42.0	220	11.93	1.42	8.05	1.49	1.83	1.60	9.14	1.69	2.07
925B	Chul	0.0	July 20	42.0	215	11.86	1.51	8.57	2.41	1.82	1.71	9.72	2.73	2.06
926A	Chul	0.0	June 10	60.0	227	11.61	1.71	9.74	3.19	2.04	1.95	11.02	3.61	2.29
926B	Chul	0.0	July 20	53.0	232	11.70	1.64	9.33	2.90	1.95	1.86	10.56	3.28	2.21
927A	Kubanka	100.0	June 21	48.0	222	11.95	1.71	9.74	3.00	1.76	1.94	11.06	3.41	1.99
927B	Kubanka	100.0	July 20	35.0	241	11.42	1.67	9.50	2.30	1.74	1.88	10.73	2.59	1.96
928A	Kubanka	0.0	June 21	49.0	249	11.50	1.70	9.66	1.75	1.74	1.92	10.92	1.97	1.97
928B	Kubanka	0.0	July 20	54.0	273	11.73	1.59	9.04	3.16	1.94	1.80	10.24	3.46	2.19
929A	Kubanka	0.0	June 21	36.0	242	11.52	1.69	9.61	2.98	1.83	1.91	10.87	3.37	2.07
929B	Kubanka	0.0	July 20	35.0	241	11.72	1.62	9.22	3.00	1.83	1.84	10.45	3.39	2.07
930A	Fretes	83.3	June 21	63.0	235	11.99	1.77	10.06	4.11	1.91	2.01	11.43	4.89	2.27
930B	Fretes	83.3	July 20	63.0	230	12.09	1.85	10.51	3.70	1.93	1.93	11.95	4.13	2.15
931A	Erivan	80.9	June 21	73.0	365	11.56	1.61	9.21	2.93	1.95	1.83	10.42	3.31	2.20
931B	Erivan	80.9	July 20	67.0	363	11.50	1.57	8.93	2.51	2.02	1.77	10.09	2.83	2.28
932A	Gharnovka	21.4	June 21	37.0	266	12.07	1.60	9.07	2.98	1.68	1.81	10.32	3.39	1.89
932B	Gharnovka	21.4	July 20	......	267	11.66	1.74	9.93	3.20	1.73	1.98	11.34	3.62	1.95
933A	Koola	87.0	June 21	52.0	255	11.88	1.81	10.28	3.24	1.91	2.05	11.66	3.67	2.16
933B	Koola	78.0	July 20	45.0	275	12.02	1.48	8.43	3.22	1.84	1.69	9.58	3.66	2.09
934A	Kubanka	78.0	June 21	......	225	11.75	1.65	9.34	3.61	1.74	1.87	10.59	4.09	1.97
934B	Kubanka	87.0	July 20	......	218	11.51	1.60	9.09	3.00	1.81	1.81	10.27	3.39	2.04
935A	Velvet Don	44.1	June 21	51.0	280	11.78	1.81	10.28	2.95	1.78	2.05	11.65	3.34	2.02
935B	Velvet Don	44.1	July 20	43.0	273	11.61	1.57	8.93	2.96	1.74	1.78	10.11	3.34	1.96

TABLE 10.—SHOWING PHYSICAL AND CHEMICAL DEVIATION FROM TYPE IN EARLY AND LATE HARVESTED WHEATS—(*Continued*)

YUBA CITY, 1907

Lab. No.	Name	Per cent typical seed in original	Date of harvest	Per cent typical seed in progeny	Number kernels in 10 grams	As analyzed: Moisture	As analyzed: Total nitrogen	As analyzed: Total protein	As analyzed: Gliadin	As analyzed: Ash	Calculated to dry basis: Total nitrogen	Calculated to dry basis: Total protein	Calculated to dry basis: Gliadin	Calculated to dry basis: Ash
847	Kubanka	100.0	July 2	48.6	......	13.24	1.69	9.58	3.37	1.71	1.95	11.03	3.88	1.97
848	Kubanka	100.0	July 24	49.5	......	12.80	1.73	9.82	2.83	2.02	1.99	11.26	3.31	2.32
850	Kubanka	0.0	July 2	48.3	203	13.08	1.61	9.20	1.90	1.67	1.87	10.58	2.17	1.92
851	Kubanka	0.0	July 24	42.3	210	13.09	1.76	10.00	3.01	1.62	2.02	11.51	3.55	1.90
853	Kubanka	0.0	July 2	38.9	224	13.50	1.60	9.07	2.79	1.98	1.60	9.07	3.23	2.28
854	Kubanka	0.0	July 24	50.3	219	12.99	1.67	9.47	2.99	1.77	1.77	10.07	3.43	2.02
856	Chul	100.0	June 29	58.1	......	12.98	1.49	8.47	3.49	2.01	1.71	9.74	......	2.31
856	Chul	100.0	July 12	55.8	192	14.08	1.24	7.04	2.83	1.63	1.45	8.19	3.29	1.89
857	Chul	0.0	June 29	87.7	200	13.88	1.19	6.73	2.97	1.49	1.37	7.81	3.45	2.15
858	Chul	0.0	July 12	68.0	200	13.71	1.28	7.29	2.78	1.74	1.49	8.44	3.23	2.02
861	Kharkov	93.1	Aug. 7	83.9	310	11.64	2.07	11.75	3.16	2.07	2.19	12.44	3.66	2.40
860	Kharkov	93.3	Sept. 13	86.1	276	11.18	......	....	......	......	......	12.70	3.63	2.28
862	Weissenberg	87.7	July 7	89.1	270	13.67	2.44	13.87	4.36	2.06	2.82	16.06	5.06	2.38
863	Weissenberg	87.7	Sept. 6	99.3	278	12.79	3.06	17.53	4.23	2.17	3.52	20[illegible]0	4.75	2.48
866	Fretes	100.0	July 2	83.5	225	12.85	1.73	9.82	3.17	2.12	1.98	11.27	3.72	2.43
867	Fretes	100.0	Sept. 6	63.1	147	12.82	1.70	9.64	3.39	1.97	1.96	11.05	3.88	2.26
868	Kubanka	63.4	July 8	89.2	184	13.36	3.57	20.48	4.05	1.95	4.14	23.64	4.68	2.22
869	Kubanka	63.4	Sept. 5	88.3	179	....	......	....	......	......	......	....	......	......
870	Velvet Don	79.5	July 2	90.1	239	12.84	2.14	12.17	4.12	2.27	2.46	13.96	4.75	2.61
871	Velvet Don	79.5	Aug. 6	96.1	216	13.17	2.09	11.94	4.53	2.22	2.43	15.76	5.21	2.56
872	Gharnovka	6.5	July 2	66.9	210	12.06	1.91	10.84	3.08	1.74	2.12	12.05	3.50	......
873	Gharnovka	6.5	Aug. 6	76.5	206	13.70	1.91	10.83	2.68	2.14	2.20	12.46	3.12	......
874	Beloglina	59.9	July 23	77.4	314	12.72	1.83	10.40	3.42	2.21	2.09	11.91	3.91	2.54
876	Beloglina	59.9	Sept. 7	91.9	356	11.82	2.06	11.71	1.95	2.25	2.33	13.27	2.21	2.55
877	Currell	....	July 22	87.9	323	13.25	2.07	11.73	4.34	1.84	2.38	13.52	4.00	2.12
879	Currell	....	Sept. 13	78.6	351	13.11	2.08	11.78	4.39	1.90	2.39	13.55	5.05	2.02

TABLE 10.—SHOWING PHYSICAL AND CHEMICAL DEVIATION FROM TYPE IN EARLY AND LATE HARVESTED WHEATS—(*Concluded*)

TULARE, 1907

						As analyzed					Calculated to dry basis			
Lab. No.	Name	Per cent typical seed in original	Date of harvest	Per cent typical seed in progeny	Number kernels in 10 grams	Moisture	Total nitrogen	Total protein	Gliadin	Ash	Total nitrogen	Total protein	Gliadin	Ash
892	Beloglina	66.1	June 21	59.4	271	13.21	1.67	9.51	3.33	2.04	1.93	10.[illegible]6	3.83	2.35
893	Beloglina	66.1	July 29	57.7	278	13.71	1.60	9.14	3.19	1.73	1.86	10.96	3.69	2.00
894	Velvet Don	79.8	June 6	93.5	249	13.31	1.48	8.10	2.63	1.97	1.65	9.34	3.04	2.27
895	Velvet Don	79.8	July 29	84.8	226	12.91	1.87	10.59	3.77	1.86	2.15	12.17	4.33	2.26
899	Gharnovka	9.0	June 11	44.1	303	12.07	1.53	8.75	3.56	1.97	1.87	10.71	4.04	2.23
900	Gharnovka	9.0	July 29	46.8	232	12.97	1.76	10.00	3.12	2.07	2.12	12.06	3.58	2.37
901	Turkey Red	50.1	June 27	85.1	310	13.49	2.04	11.58	4.10	2.16	2.36	13.39	4.85	2.49
902	Turkey Red	50.1	July 29	66.9	283	14.14	1.76	10.01	3.18	1.82	2.06	11.71	3.70	2.12
904	Fretes	100.0	June 3	0.0	220	13.87	1.61	9.17	3.60	1.86	1.87	10.60	4.19	2.16
905	Fretes	100.0	July 29	32.7	229	13.54	1.23	7.00	3.41	1.70	1.42	8.10	4.06	1.95

The averages for the three localities are shown in the following small table:

TABLE SHOWING THE AVERAGE RESULTS FROM EARLY AND LATE CUT WHEATS AT THREE STATION IN 1907

		Early cut		Late cut	
	Number of trials	Per cent typical kernels	Per cent protein	Per cent typical kernels	Per cent protein
Modesto	12	52.3	9.92	49.2	10.40
Yuba City	13	73.0	11.62	73.3	12.19
Tulare	5	56.4	11.00	57.8	10.92
Grand av.	30	62.6	10.80	61.9	11.24

From a total of 30 cases, 12 showed either an equal or larger per cent of typical kernels in the late cutting than in the early cutting, a number altogether too large to indicate that the lateness of cutting had any material influence in this direction, and this is further shown from the fact that the general average shows 62.6 per cent of typical kernels in the early cut lots and 61.9 per cent in the late cut lots.

Again this is indicated in the protein content, for out of the 30 cases 15 show a larger percentage in the late cut grain than in the early cut lots, and the general average in protein content is essentially the same in the two lots, viz., 10.80 and 11.24 per cent respectively.

For the two seasons the record stands as follows:

		Early cut		Late cut	
	Number of trials	Per cent typical kernels	Per cent protein	Per cent typical kernels	Per cent protein
Modesto	27	77.68	11.8	73.7	11.95
Yuba City	29	69.1	11.96	68.5	11.20
Tulare	5	56.4	11.00	57.8	10.92
Average	61	71.1	11.80	69.9	11.51

These figures seem to show quite clearly that to allow the grain to stand on the straw until in the proper condition for handling with the combined harvester does not in any manner militate against its quality either in physical appearance or protein content, and should set at rest any further discussion upon this point.

EFFECT OF SUNSHINE ON THE COMPOSITION OF THE WHEAT KERNEL

It has long been a matter of common knowledge that the composition of plants varies greatly under different conditions and in different localities. The exact environmental factor or factors which cause this variation in composition has been the cause of much discussion and investigation.

It has already been remarked above that in 1882 Richardson observed that wheat grown in Colorado had by reputation a much higher gluten content than wheat grown from the same seed in Oregon. Not only was there a marked difference in the composition of the wheat grown in the two states, but he found that the wheat grown in Colorado had a higher gluten content than the original seed, while that grown in Oregon had a lower gluten content than the seed from which it was produced. From these observations Richardson and Blount concluded that the soil was the modifying factor.

Wiley, however, draws the conclusion that the difference in gluten content is due to climatic conditions.

Lawes and Gilbert in an elaborate series of experiments have shown that the use of manures and fertilizers have very little influence on the composition of the wheat kernel. On the other hand, they found a wide variation in composition in different seasons.

Deherain in France also observed that a difference in seasonal conditions, especially during the ripening period, had a marked influence on the gluten content of wheat.

Similar observations have been noted by Thatcher of Washington, and others.

From these numerous observations and experiments it has come to be generally conceded that the gluten content is influenced mostly, if not wholly, by the climate.

Wheat grown in the coast states is, as a class, much lower in gluten content than wheat grown in the central west, or the northwestern states. Even when seed of a high gluten content is introduced, a product, as Richardson observed, considerably inferior is the result.

Climate includes a large number of factors. The specific climatic factor which is the cause of this variation has recently been the subject of much study and investigation.

The formation of organic compounds in the plant, such as starch and gluten, is a physiological process. The maximum development of these compounds is necessarily dependent upon favorable conditions. Starch is formed under the influence of sunlight. The formation of nitrogenous compounds requires not only an adequate supply of nitrogen, but also a supply of carbon compounds in the proper form and under the proper conditions. Just what these conditions are is not definitely known.

In general, investigators have concluded that the large amount of sunshine prevalent in the coast states during the period in which the seed develops works directly in favor of the formation of large amounts of starch. In other words, that the gluten content is low only by reason of the formation of proportionally larger amounts of starch. Were this the case, the exclusion of portions of the sunlight should tend to increase the percentage of gluten. Theoretically the gluten would increase inversely with the amount of sunlight which the plants received.

In order to determine whether or not sunlight is a prominent factor a series of experiments were planned in which portions of the natural sunlight were excluded from the growing plants.

Duplicate experiments were conducted during the seasons of 1908 and 1909 at the Tulare Sub-station and at the University Farm at Davis.

Original Seed.—At the Tulare Station in 1908 the originals used were as follows:

No. 864/07	Weissenberg
No. 879/07	Currell
No. 892/07	Beloglina
No. 894/07	Velvet Don (starch grains)
No. 901/07	Turkey Red (gluten grains)
No. 899/07	Yellow Gharnovka (gluten grains)

At Davis the following varieties were used:

No. 868/07	Kubanka
No. 847	Kubanka
No. 870A	Velvet Don (gluten grains)

The originals showed the following composition:

AT TULARE

Lab. No.	Name	Per cent typical kernels	Kernels in 10 grams	Per cent protein	Per cent gliadin	Per cent ash
864	Weissenberg	95.9	325	15.25	3.63	2.66
879	Currell	87.6	351	13.55	5.06	2.11
892	Beloglina	59.4	271	10.96	3.84	2.33
894	Velvet Don	0.0	230	8.79	2.90	2.00
901	Turkey Red	100.0	278	13.41	5.28	1.99
899	Gharnovka	100.0	280	12.20	4.26	2.02

AT DAVIS

Lab. No.	Name	Per cent typical kernels	Kernels in 10 grams	Per cent protein	Per cent gliadin	Per cent ash
868	Kubanka	89.2	184	23.64	4.67	2.22
847	Kubanka	48.6	......	11.03	3.88	1.97
870–G	Velvet Don	90.1	239	17.38	4.80	2.05

Two rows of each of these varieties were drilled parallel into a bed 24 feet long. In the spring after the grain began to make an upright growth a series of lath screens was constructed and placed across the plat so as to shut off different proportions of the direct sunshine. The plat was thus divided into sections. At Tulare sectional screens were arranged so that they excluded three quarters, one half, and one quarter of the sunshine respectively. One quarter was left unshaded, and this received the full sunshine. In this manner one fourth of each variety received the same amount of sunshine. At Davis a similar arrangement was used, except that the amount of sunshine admitted was one third, one half, two thirds, and full. These screens were left in place until the grain was matured and harvested. Each portion of each variety thus treated was harvested separately and taken to the laboratory for analysis. The results are stated below:

TABLE 12.—SHOWING EFFECT OF VARIOUS AMOUNTS OF SUNSHINE ON THE GLUTEN CONTENT OF WHEAT

TULARE, 1908

	One-quarter sunshine		One-half sunshine		Three-quarters sunshine		Full sunshine	
	Total gluten	Gliadin	Total gluten	Gliadin	Total gluten	Gliadin	Total gluten	Gliadin
864	17.55	8.000	18.00	8.065	....	......	20.73	9.599
894	12.10	4.930	12.72	5.350	....	......	13.57	4.856
899	12.66	5.333	12.61	5.311	....	......	13.63	5.515
901	15.33	6.602	15.45	6.986	....	......	16.13	6.545
879	18.17	8.000	18.63	8.406	....	......	18.34	8.463
892	15.39	6.674	16.58	7.157	....	......	17.04	7.554
Av.	15.19	6.589	15.665	6.879	....	......	16.57	7.088
Gliadin ratio	43.40		43.91		......		42.77	

DAVIS, 1908

	One-third sunshine		One-half sunshine		Two-thirds sunshine		Full sunshine	
	Total gluten	Gliadin	Total gluten	Gliadin	Total gluten	Gliadin	Total gluten	Gliadin
868	13.19	4.17	13.94	4.17	14.10	4.42	13.79	4.28
847	12.69	4.46	12.37	4.09	13.40	3.50	12.47	4.00
870G	14.30	4.71	....	......	13.53	4.21	13.17	4.52
Av.	13.39	4.445	13.15	4.13	13.67	4.034	13.14	4.266
Gliadin ratio	33.19		31.40		29.57		32.46	

EXPERIMENTS OF 1909

During the season of 1909 the same experiment was conducted at the Tulare and Davis Stations, with the exception that the following varieties of wheat were used:

Gluten grains from Richi 1044A;
Gluten grains from Kubanka 1045A;
Starch grains from Kubanka 1045A;
Gluten grains from Turkey 1046A;
Gluten grains from Beloglina 1047A;
Starch grains from Beloglina 1047A.

Determinations made upon these previous to seeding showed as follows:

No.	Typical kernels	Kernels in 10 grams	Protein	Gliadin	Ash
1044A–G	100.0	189	10.42	3.17	1.90
1045A–G	100.0	197	13.09	4.32	1.74
1045A–S	0.0	220	9.37	2.59	1.88
1046A–G	100.0	389	15.43	4.90	2.21
1047A–G	100.0	372	16.11	5.33	2.25
1047A–S	0.0	329	7.37	2.00	1.77

At Davis the originals and their analyses were as follows:

No.	Name	Typical kernels	Kernels in 10 grams	Protein	Gliadin	Ash
870G	Velvet Don	100.0	227	15.92	4.27	2.02
870S	Velvet Don	0.0	239	13.96	4.73	2.61
1045A–G	Kubanka	100.0	197	13.09	4.32	1.74
1045A–S	Kubanka	0.0	220	9.37	2.59	1.88
1041A–G	Kubanka	100.0	177	13.05	4.12	2.02
1041A–S	Kubanka	0.0	194	10.56	2.99	2.01

The gluten and gliadin content of the wheat samples from the experiments of 1909 are reported in Table 13.

TABLE 13.—SHOWING EFFECT OF VARIOUS AMOUNTS OF SUNSHINE ON THE PROTEIN CONTENT OF WHEAT

TULARE, 1909

	One-quarter sunshine		One-half sunshine		Three-quarters sunshine		Full sunshine	
	Total protein	Gliadin	Total protein	Gliadin	Total protein	Gliadin	Total protein	Gliadin
46G	10.62	3.516	7.38	5.043	....	....	14.77	5.651
47AS	10.96	3.998	12.32	4.413	15.56	5.577	13.18	4.084
47AS	....	....	....	....	....	....	13.74	4.737
45AS	11.64	4.100	12.04	4.271	13.86	3.783	13.35	3.839
45AG	12.38	3.902	13.25	4.674	11.30	4.312	13.91	4.981
44AG	10.90	3.271	11.41	3.436	14.99	4.385	11.59	3.720
Av.	11.30	3.757	11.27	4.368	13.92	4.514	13.42	4.502
din ratio	33.42		38.74		32.42		33.54	

DAVIS, 1909

	One-third sunshine		One-half sunshine		Two-thirds sunshine		Full sunshine	
	Total protein	Gliadin	Total protein	Gliadin	Total protein	Gliadin	Total protein	Gliadin
41AS	15.34	4.845	16.24	4.850	16.41	5.151	16.02	4.970
45AG	14.71	5.186	14.37	4.748	15.50	4.055	14.48	4.635
45AS	14.71	5.680	*........	....	15.56	6.248	14.25	5.850
70AG	16.53	5.341	*........	....	15.62	4.867	15.66	5.214
70AS	15.79	6.816	14.06	3.770	15.50	6.418	15.50	6.645
41AG	16.36	6.832	16.70	6.475	17.09	6.929	16.30	6.418
Av.	15.57	5.773	15.34	4.960	15.94	5.611	15.37	5.622
din ratio	36.82		32.33		35.20		36.57	

* There was not enough material for a re-analysis of the sample.

Discussion.—If the proportion of protein to starch, or the percentage of nitrogen, increased inversely as the amount of sunshine the plants received we would expect the percentage of protein to be highest in the plants receiving only one quarter of the total sunshine and to decrease gradually to full sunshine. This, however, does not seem to be the case. Taking the average of the six samples grown at the Tulare station in 1908, we find just the opposite result. The protein content increases with the sunshine quite uniformly. The wheat from the plants receiving one-half sunshine contain .47 per cent more protein than the wheat from those receiving one-quarter sunshine. The wheat receiving full sunshine contained .91 per cent more than those receiving only one-half sunshine. Unfortunately the samples grown under three-quarters sunshine were lost, so that we are unable to say whether or not the protein content here would have been above or below that of full sunshine.

The analysis of the individual samples in this set show that only one departs markedly from the average. In the variety no. 879 we find that the wheat grown under one-half sunshine had a higher protein content by .29 per cent than did that grown under full sunshine, while that grown under one-quarter sunshine is the lowest of the three by .17 per cent. In sample no. 899 we find that one-quarter and one-half sunshine gave nearly the same results, with a slight difference in favor of the former.

The general trend of the results from 1909 experiments is much the same. The average of the samples grown under one-quarter and one-half sunshine are about equal, while the protein content of those grown under three quarters and full sunshine are much higher. If we exclude sample no. 1046G grown under one-half sunshine, which is unusually low, the average for one-half sunshine is 12.25 per cent. This gives, then, quite a gradual increase in protein content from one quarter to three quarters sunshine, while the full sunshine samples average .5 per cent lower than those receiving only three-quarters sunshine.

The results from the experiments at Davis are slightly more erratic, but the general trend is the same as that obtained at Tulare during the season of 1909. The samples under one third sunshine average .24 per cent more protein than did those under

one-half sunshine. The samples under two-thirds sunshine averaged .52 per cent more protein than those under one-half sunshine, and .28 per cent more than those under one-third sunshine. There was, then, a drop in the full sunshine sample to about the same protein content as those receiving one-half sunshine.

The results for 1909 at Davis came in the same order as those of 1908. The samples under one-third sunshine average higher in protein than those under one-half sunshine by .23 per cent. The samples under two-thirds sunshine averaged higher than those under one-half by .6 per cent, and than those under one-third sunshine by .37 per cent, while the average of the samples grown under full sunshine is nearly the same as of those grown under one-half sunshine.

These results certainly show that the protein content does not vary inversely with the amount of sunshine which the plants receive. On the other hand, the experiments at Davis and those of the year 1909 at Tulare tend to show that there is a happy medium under which the maximum amount of protein is stored. This optimum condition seems to be at a point somewhat below the normal sunshine. If, however, the amount of sunshine falls below that medium then again there is a decrease in the amount of protein stored. Just why this should be the case is still a matter of conjecture. It is quite probable, however, that it is due to a disturbed condition of the physiological functions within the plant brought about by the abnormally low sunshine. This fact can only be determined by a closer study of the formation and transformation of the various compounds in the plant.

The gliadin content of the samples in this experiment seems to bear even less relation to the sunshine than did the total protein. In fact, there was no regularity whatever in the results those obtained at Tulare being just opposite from those obtained at Davis.

A comparison of the two years at the two stations shows that there was a marked difference in the protein content of the samples in different seasons. At Davis we find that the samples averaged a higher percentage of gluten in 1909 than in 1908 by over 2 per cent.

Comparing the weather reports at Davis for the months of April, May, and June, we find that this period during 1909 was much drier and somewhat warmer than the corresponding months the year before. As this is the time when the greatest development of the kernel takes place, it is not at all unlikely that these climatic differences may account to some extent for the differences in composition of the grain. The moister and cooler condition of 1908 may have prolonged the developing and ripening period, thus favoring the storing of a larger amount of starch. Other seasonal differences not recorded have doubtless also contributed their share.

The difference in protein content for the two seasons at Tulare is just as marked as at Davis, but the order is reversed. No weather reports from the immediate vicinity were available, so we can make no comparison with the Davis conditions.

Another rather striking seasonal difference brought out by the table is the percentage of gliadin to total protein. The years that the percentage of total protein is high, the percentage of gliadin to total gluten is also high. In fact, the difference in the gliadin content of the wheat samples for the two years is proportionally greater than the difference in total protein. This would lead us to believe that the gliadin is affected more by the season than the other protein compounds. We find, however, little or no relation between the gliadin content and the sunshine received.

In conclusion, then, it is safe to say that while sunshine does exert some influence upon the composition of the wheat grain, there are other climatic factors which also exert very marked influences in this direction. We find that the protein does not increase inversely as the sunshine, but that there is an optimum condition under which the greatest development of protein takes place. This optimum of sunshine is somewhat less than normal in the valleys of this state. Other things being equal, too little sunshine lowers the protein content to just as great an extent as too much sunshine. This condition is probably due to the fact that a certain amount of sunshine is necessary in order that the normal physiological functions of the plant may take place. When the amount of sunshine is reduced to one quarter or one

half of the normal it is quite likely that the plants do not receive enough sunshine to allow even the maximum nitrogen metabolism to take place.

The fact that there is a greater difference in the percentage of protein for different seasons than there is in the same season under various amounts of sunshine certainly tends to show that there are factors other than sunshine, which play just as important a part in determining the composition of the grain.

Certain experimenters have stated that the exposure of grain to the action of strong sunlight after it had become ripe had a tendency not only to bleach the kernels, forming the so-called "yellow berry," but also to lower the protein content. Attention was called to this by Lyon and Keyser based upon some trials made at the Nebraska station. On account of the fact that the sunshine in the main grain-growing regions of California is very intense during the ripening and harvesting period, and that the grain frequently stands for several weeks on the straw in the field, an attempt was made in 1906 at Yuba City to ascertain if this effect held under the conditions which obtain in this state. In this experiment several varieties of wheat were selected in which differences in the physical appearances of the grain could be easily followed owing to the color of the typical and changed kernels. The percentage of typical kernels in the original was determined, using 5000 kernels in each case as a basis, and these were seeded in plats under like conditions in the field. At the maturity of the grain three fourths of the grain was cut while in the hard dough stage, a few bundles being shocked and left in the field, while an equal number were protected from the direct action of the sunlight. The remainder of the grain was left on the standing straw from July 5 to August 13, when it was harvested and all three lots were threshed at the same time. The experiment was repeated again in 1907. A determination was made of the percentage of typical kernels in each lot, and of the percent of protein. The results follow:

TABLE 14. SHOWING THE PHYSICAL AND CHEMICAL COMPOSITION OF WHEAT KERNELS EXPOSED AND PROTECTED FROM DIRECT SUNLIGHT

SEASON OF 1906

Lab. No.	Name	Treatment	Date of harvest	Typical kernels Per cent	As analyzed				Calculated to dry matter		
					Moisture	Total nitrogen	Total protein	Ash	Total nitrogen	Total protein	Ash
681	Beloglina	Cut and left exposed	July 5	62.1	11.03	1.78	10.11	2.03	2.00	11.40	2.28
695	Beloglina	Cut and protected	July 5	66.1	10.63	1.94	11.02	2.07	2.19	12.48	2.34
682	Beloglina	Left on straw in field	Aug. 13	59.9	10.49	1.81	10.27	2.00	2.02	11.51	2.24
696	Gharnovka	Cut and left exposed	July 5	6.5	11.28	1.55	2.80	2.02	1.74	9.92	2.27
675	Gharnovka	Cut and protected	July 5	15.3	11.04	1.48	8.38	1.90	1.67	9.52	2.13
676	Gharnovka	Left on straw in field	Aug. 13	9.0	11.09	1.56	8.89	2.01	1.75	9.98	2.26

TABLE 14.—SHOWING THE PHYSICAL AND CHEMICAL COMPOSITION OF WHEAT KERNELS EXPOSED AND PROTECTED FROM DIRECT SUNLIGHT—(*Continued*)

Lab. No.	Name	Treatment	Date of harvest	Typical kernels Per cent	As analyzed				Calculated to dry matter		
					Moisture	Total nitrogen	Total protein	Ash	Total nitrogen	Total protein	Ash
861	Kharkov	Cut and left exposed	Aug. 7	83.9	13.64	1.89	10.75	2.07	2.18	12.44	2.40
859	Kharkov	Cut and protected	Aug. 6	92.4	12.03	2.26	12.91	2.27	2.58	14.68	2.63
860	Kharkov	Left on straw in field	Sept. 13	86.1	11.18	1.98	11.28	2.03	2.23	12.70	2.29
863	Weissenberg	Cut and left exposed	July 23	96.7	13.46	2.78	15.85	2.02	3.22	18.35	2.33
864	Weissenberg	Cut and protected	July 23	95.9	13.27	2.32	13.25	1.91	2.68	15.25	2.21
865	Weissenberg	Left on straw in field	Aug. 8	99.3	12.79	3.07	17.53	2.17	3.52	20.10	2.49
877	Currel	Cut and left exposed	July 22	87.9	13.25	2.06	11.73	1.84	2.38	13.52	2.12
878	Currell	Cut and protected	July 22	87.5	12.45	2.01	11.47	1.87	2.28	12.96	2.15
879	Currel	Left on straw in field	Sept. 13	87.6	13.11	2.07	11.78	1.90	2.38	13.55	......
874	Beloglina	Cut and left exposed	July 22	77.4	12.72	1.83	10.40	1.93	2.09	11.91	2.22
875	Beloglina	Cut and protected	July 22	94.8	12.97	2.11	12.06	1.44	2.44	13.86	1.65
876	Beloglina	Left on straw in field	Sept. 7	91.2	11.82	2.05	11.71	1.98	2.53	13.27	2.25
	Average	Cut and left exposed	....	69.1	....	......	....	......	......	12.92	......
	Average	Cut and protected	....	75.3	....	......	....	......	......	13.12	......
	Average	Left on straw in field	....	72.1	....	......	....	......	......	13.52	......

The above results are not as consistent as could be desired in answering the main question involved in this experiment and no attempt will be made to interpret them as bearing upon this particular question. They do, however, further bear out the results discussed in the experiment on the effect of allowing the grain to stand on the straw in the field after reaching the hard dough stage, for it will be noted that in four out of six cases there was a larger percent of typical kernels in the late cut samples than in those early cut, and in one other case (no. 879) the percentage was essentially the same in the late cut sample as in that early cut. In the matter of total protein, *the late cut grain all carried a higher percentage than did those of the early cutting.*

The average results from this standpoint are shown below:

	Per cent typical kernels	Per cent total protein
Early cut	69.1	12.92
Late cut	72.1	13.52

THE EFFECT OF IRRIGATION UPON THE PROTEIN CONTENT OF WHEAT

The idea has been quite current among observant growers that whenever the rains extended late into the spring the quality of the grain of that season was materially reduced, that this had much to do with the wide seasonal differences in the quality of grain in California, and possibly was the main factor in causing such differences. This idea is quite in harmony with what has been observed in other experiments as to the effect of irrigation upon the quality of grain. No definite data being at hand as referring to conditions in California, in 1908–09 trials were made with six types of wheat at Davis to determine the effect of early and late application of water to growing wheat by planting these six types on uniform soil in rows at about the ordinary rate of seeding on three different plats. The plats received the following treatment so far as water was concerned:

Plat A received irrigation.

Plat B was irrigated in the rows once just after the grain was out of the boot.

Plat C was irrigated in the same manner twice, once at the same period in the plants' growth as in Plat B and again just after the grain set.

All plats, then, received the rainfall of the season and Plat B in addition had one irrigation and Plat C had two irrigations, the last one very late in its period of growth.

The wheats used in the experiment and their original compositions were as follows:

TABLE SHOWING THE ANALYSIS OF ORIGINAL WHEATS USED IN IRRIGATION TRIALS AT DAVIS, CAL.

No.	Per cent typical kernels	Number kernels in 10 grams	Per cent total protein	Per cent gliadin	Per cent ash
730/06	96.0	276	12.83	4.97	2.32
726/06	87.7	245	13.55	4.42	2.20
870/07	....	227	15.92	4.27	2.02
1049/08	73.9	313	12.50	4.24	1.99
870/07	90.1	239	12.17	4.12	2.27
338a2	100.0	284	11.28	......	2.13

The grains were seeded on December 7. They all came up with a good stand on December 28–31 and were harvested in two lots on June 24 and 30, there being but one or two days difference in the time of ripening between the irrigated and the non-irrigated plats.

The analysis of the several lots grown on each plat is shown in the following table:

CUT EARLY

Lab. No.	Plat A—No irrigation: Per cent typical kernels	Number kernels in 10 grams	Per cent protein	Per cent gliadin	Per cent ash	Plat B—One irrigation: Per cent typical kernels	Number kernels in 10 grams	Per cent protein	Per cent gliadin	Per cent ash	Plat C—Two irrigations: Per cent typical kernels	Number kernels in 10 grams	Per cent protein	Per cent gliadin	Per cent ash
730	87.0	272	14.42	5.26	1.83	86.0	270	13.06	4.99	2.09	90.0	280	13.60	4.46	2.03
726	98.0	221	15.22	4.85	1.82	57.0	197	12.38	4.46	1.93	22.0	198	11.02	3.08	1.98
807a08	99.0	223	14.57	4.55	1.86	99.0	218	14.51	4.30	2.05	81.0	197	12.95	4.51	1.87
1049	.....	.....	....	.....	.....	79.0	253	11.98	4.00	1.69	80.0	258	12.52	4.77	1.63
870	97.0	213	15.08	5.43	1.78	95.0	215	13.63	4.34	1.88	97.0	213	11.64	3.88	1.72
338a	95.0	260	13.52	5.41	2.00	90.0	258	13.12	4.94	2.10	95.0	262	14.88	4.00	1.78
Av.	95.2	239	14.56	5.10	1.86	82.3	235	13.11	4.51	1.96	77.5	234	12.77	4.12	1.84

CUT LATE

Lab. No.	Plat A—No irrigation: Per cent typical kernels	Number kernels in 10 grams	Per cent protein	Per cent gliadin	Per cent ash	Plat B—One irrigation: Per cent typical kernels	Number kernels in 10 grams	Per cent protein	Per cent gliadin	Per cent ash	Plat C—Two irrigations: Per cent typical kernels	Number kernels in 10 grams	Per cent protein	Per cent gliadin	Per cent ash
730	81.0	265	15.76	5.93	1.99	90.0	283	15.48	4.88	1.98	80.0	285	13.63	4.89	2.08
726	88.0	193	13.38	4.28	1.86	93.0	184	14.37	5.07	1.93	91.0	185	13.97	4.34	1.83
807a08	99.0	220	14.08	5.54	1.96	99.0	203	14.57	5.29	1.83	93.0	215	14.26	4.76	1.78
1049	92.0	284	15.62	6.60	1.73	92.0	264	13.86	5.63	1.90	91.0	280	15.11	5.89	1.77
807/07	99.0	226	14.88	4.96	1.74	99.0	203	13.30	4.16	2.06	99.0	220	14.11	4.75	1.73
338a	99.0	260	15.25	5.77	1.82	94.0	275	15.08	5.60	1.80	79.0	270	13.18	4.81	1.91
Av.	93.0	241	14.83	5.35	1.85	94.5	235	14.44	5.12	1.92	88.8	242	14.04	4.91	1.85

Examining these results, it will be seen that in both the early and late cut lots Plat A, which received no late application of water, carried the highest average per cent of protein, and that Plat C, which had two water applications, carried the lowest. Averaging the early and late cut lots, the following figures hold:

	Per cent typical kernels	Number kernels in 10 grams	Per cent protein	Per cent gliadin	Per cent ash
Plat A	94.1	240	14.70	5.22	1.85
Plat B	88.1	235	13.78	4.81	1.94
Plat C	83.1	238	13.40	4.51	1.84

This shows a gradual decrease in both the protein and gliadin content as the moisture was increased, is in entire harmony with results cited elsewhere, and seems to show that either irrigation or late rains tend to lower the gluten content of wheat, and that this climatic factor is a very prominent, if not the most important one in causing seasonal variation in the grain.

Comparing the early cutting with the late cutting, it will be seen that while there is some fluctuation between corresponding samples in the two cuttings, the averages bear out the experiments cited in the earlier pages to the effect that no deterioration occurs from such late cutting, and as a matter of fact in this series of trials there was an actual increase in the protein content in the late compared with the early cutting.

THE EFFECT OF REDUCING THE ATMOSPHERIC TEMPERATURE AT NIGHT UPON THE PROTEIN CONTENT OF WHEAT

In the season 1907–08 an attempt was made to reduce the temperature, at different stages of plant growth, on certain plats on which were seeded several types of grain and to compare the protein content on these plats.

The general plan of this experiment consisted of seeding several types of wheat in rows upon adjacent small plats of uniform soil. The rows were seeded north and south, and to prevent the plats from receiving the early sun and to assist in holding down the temperature in the early morning across the south end of the plats cooled during the first period of growth, a board fence was erected sufficiently high to shade during the

morning hours about one half of each plat throughout the period of cooling. From the time the grains were well up until the spring rains ceased a layer of ice was spread on a loose frame and placed over one half of each plat, within four inches of the top of the plants, every night during the first half of the growing period of the plants. A portion of the north half of each plat was left uniced. To retain more effectively the cooled air during the night the iced portion of the plats was entirely covered by a piece of heavy canvas.

In this experiment two varieties of common wheats and five strains of durum wheats were used. The composition of each sample harvested is shown below:

TABLE 14.—SHOWING EFFECT OF REDUCING NIGHT TEMPERATURE UPON THE COMPOSITION OF WHEAT KERNELS

NOT COOLED

Lab. No.	Name	Per cent typical kernels	Number kernels in 10 grams	Per cent protein	Per cent gliadin	Per cent ash
745B/08	Kubanka 1440	98.65	217	15.04	5.10	1.84
851/08	Kubanka 2221	99.8	201	15.19	5.09	1.92
869/08	Kubanka 2239	99.6	177	15.77	5.44	1.87
871/08	Velvet Don	99.5	205	15.44	5.31	1.96
872/08	Gharnovka	99.5	207	15.15	5.09	1.83
920/08	Red Fife	96.9	361	17.40	5.82	2.19
962/08	White Fife	100.0	323	16.49	5.65	1.97
Average		99.1	241	15.78	5.36	1.93

COOLED FIRST PERIOD

Lab. No.	Name	Per cent typical kernels	Number kernels in 10 grams	Per cent protein	Per cent gliadin	Per cent ash
745B/08	Kubanka	99.75	254	14.95	4.52	1.88
851/08	Kubanka 2221	99.70	233	15.31	4.96	1.23
869/08	Kubanka 2239	100.00	213	14.61	5.27	2.04
871/08	Velvet Don	99.94	229	15.87	5.32	1.86
872/08	Gharnovka	100.0	241	15.60	4.67	1.90
920/08	Red Fife	100.00	384	17.76	......	2.26
962/08	White Fife	100.00	380	18.24	5.75	2.41
Average		99.9	276	16.05	5.08	1.98

COOLED SECOND PERIOD

Lab. No.	Name	Per cent typical kernels	Number kernels in 10 grams	Per cent protein	Per cent gliadin	Per cent ash
745B/08	Kubanka 1440	100.0	217	15.24	5.39	1.96
851/08	Kubanka 2221	100.0	215	15.45	4.96	1.80
869/08	Kubanka 2239	99.8	203	15.80	5.43	1.90
871/08	Velvet D	99.9	246	15.53	4.25	1.90
872/08	Gharnovka	100.0	218	16.15	4.89	1.90
920/08	Red Fife	97.5	350	17.80	5.96	2.31
962/08	White Fife	99.4	339	17.69	6.29	2.13
Average		99.6	255	16.23	5.31	1.99

Collecting the averages for comparison, the figures are as follows:

Treatment	Per cent typical kernels	Number kernels in 10 grams	Per cent protein	Per cent gliadin	Per cent ash
Not cooled	99.1	241	15.78	5.36	1.93
Cooled First Period	99.9	276	16.05	5.08	1.98
Cooled Second Period	99.6	255	16.23	5.31	1.99

While the figures for individual analyses are slightly erratic, yet it appears that the general effect of reducing the temperature in each period tended to increase the total protein, and that the tendency was greatest when the night temperature was reduced in the second period of growth, for in the case of cooling during the first period of growth five out of the seven trials showed a higher percentage of total protein than those grown under normal conditions, and the average total protein was 16.05 per cent against 15.78 in the case of the uncooled lot.

In the case of the lot cooled during the second period of growth (after the grain was in the boot) all seven showed an increased protein content over the uncooled lot, the respective averages showing 17.23 against 15.79 per cent.

Further, the effect of the cooling seems to have been greater from reducing the temperature during the second period of growth than during the first, for five of the cases in this comparison show increased protein with an average protein content of 16.23 per cent against 16.05 per cent, and a gliadin content of 5.31 per cent against 5.08 per cent.

RELATION OF INCREASING THE SEVERAL AVAILABLE PLANT FOODS IN THE SOIL TO THE PROTEIN CONTENT OF WHEATS AT THE UNIVERSITY FARM, DAVIS, 1908–12, INCLUSIVE

The general effect upon the protein content of wheat from increasing the available nitrogen and other plant food elements in the soil at the University Farm at Davis has been made the subject of study for the past four years and the results are discussed below. In these experiments Little Club wheat has been used each year. In order that any cumulative effect which might accrue from the nitrogen and the other plant foods used might be apparent, the seed from each plat was seeded back upon the same plat each succeeding season.

The original seed used in these experiments was grown in 1906, and had the following composition:

	As analyzed	In dry matter
Moisture	11.28	....
Total protein	12.12	13.66
Gliadin	4.38	4.93
Glutenin	6.38	7.19
Non-gluten proteids	1.36	1.58
Ash	1.62	1.82
Kernels in 10 grams	226	
Bushel weight	59 lbs.	

For the four years 1908, 1909, 1910, and 1912 the average result was as stated in the table below. During the season of 1911 the land was under bare summer fallow on account of its foulness with wild oats, which accounts for the omission of that year.

During these trials the one-twentieth acre plats received the indicated quantities of fertilizer each season.

TABLE 15. SHOWING THE EFFECT OF VARIOUS FERTILIZER INGREDIENTS UPON THE PROTEIN CONTENT OF WHEAT KERNELS

Fertilizer applied	Per cent total protein	Per cent gliadin	Ash
1. Nitrate of soda, 5 lbs.; hydrate of lime, 132½ lbs.	*10.36	3.000	1.75
2. Hydrate of soda, 5 lbs.	*11.08	3.280	1.73
3. Hydrate of lime, 132½ lbs.	11.41	4.037	1.93
4. Check, no fertilizer	10.81	3.869	1.98
5. Nitrate of soda, 5 lbs.; sulphate of potash, 6 lbs.	10.99	3.816	1.95
6. Nitrate of soda, 10 lbs.	11.00	4.130	1.99
7. Check, no fertilizer	11.18	3.866	1.86
8. Nitrate of soda, 5 lbs.; superphosphate, 20 lbs.	11.02	3.855	1.82
9. Nitrate of soda, 10 lbs.; sulphate of potash, 6 lbs.	11.91	4.416	1.80
10. Nitrate of soda, 10 lbs.; superphosphate, 30 lbs.	10.93	3.728	1.83
11. Check, no fertilizer	9.99	3.793	1.87
12. Superphosphate, 20 lbs.	10.64	3.888	1.86
13. Sulphate of potash, 6 lbs.	10.82	4.054	1.81
14. Check	10.77	3.978	1.79
15. Nitrate of soda, 5 lbs.; sulphate of potash, 12 lbs.	10.94	3.806	1.82
16. Nitrate of soda, 5 lbs.; superphosphate, 30 lbs.	10.57	3.878	2.20
17. Nitrate of soda, 10 lbs.; superphosphate, 30 lbs.; sulphate of potash, 12 lbs.	10.76	3.870	1.90
18. Nitrate of soda, 5 lbs.; superphosphate, 30 lbs.; sulphate of potash, 6 lbs.	11.00	4.291	1.87
19. Nitrate of soda, 5 lbs.; superphosphate, 30 lbs.; sulphate of potash, 12 lbs.	11.35	4.703	1.90
20. Nitrate of soda, 5 lbs.; superphosphate, 50 lbs.; sulphate of potash, 6 lbs.	11.92	4.815	1.91
21. Check	10.58	4.312	1.82
22. Sulphate of potash, 6 lbs.; superphosphate, 30 lbs.	11.06	4.617	1.81
23. Dry blood, 7 lbs.; superphosphate, 30 lbs.; sulphate of potash, 6 lbs.	11.24	4.748	1.86
24. Legume, 1907–08; nothing, 1908–09; superphosphate, sulphate of potash, 1909–10	12.27	5.720	1.87
25. Superphosphate, 30 lbs., sulphate of potash, 6 lbs., 1907–08; legume, 1908–09; nothing, 1909–10	12.86	5.440	2.03

* Plats 1 and 2 were discontinued in 1910 on account of building and plats 28 and 29 substituted.

TABLE 15—(*Continued*)

Fertilizer applied	Per cent total protein	Per cent gliadin	Ash
26. Sulphate of potash, 6 lbs., superphosphate, 30 lbs., 1908–09; nothing, 1907–08; legume, 1909–10	12.51	5.287	1.71
27. Check, no fertilizer	11.23	4.692	1.93
28. Nitrate of soda, 5 lbs.; hydrate of lime, 132½ lbs.	*11.91	5.265	1.86
29. Nitrate of soda, 5 lbs.	*11.89	5.065	2.14

* Plats 1 and 2 were discontinued in 1910 on account of building and plats 28 and 29 were substituted.

THE EFFECT OF NITROGEN

Collecting the results as to the effect of nitrogen upon the protein content, the following figures hold:

Plats receiving nitrogen		Check plats	
Plat No.	Per cent protein	Plat No.	Per cent protein
1	10.36	3	11.41
2	11.08	4	10.81
Av. for 2 yrs.	10.67		11.11

Plat No.	Per cent protein	Plat No.	Per cent protein
9	11.91	5	10.99
6	11.00	7	11.18
5	10.99	13	10.82
10	10.93	12	10.64
17	10.76	19	11.35
10	10.93	12	10.64
23	11.24	22	11.06
Average	11.10		10.95

From the above it does not appear that increasing the available nitrogen content of the soil in these trials has had any material influence in increasing the nitrogen in the grain, nor has there been any cumulative effect shown by its use. This is shown by the individual cases as well as in the general averages. Considering individual cases, Plat 5 and Plat 6 may be compared, each receiving equal amounts of potash, while the former received also 100 pounds of nitrate of soda per acre, but it carried only .17 per cent more protein than the plat receiving no nitrate. Plat 6 received an application of 200 pounds of nitrate of soda,

while Plat 7 received no fertilizer, and yet the average protein content of the latter shows .18 per cent higher than the former. Further, in the case where a complete fertilizer was used, as in Plats 17 and 19, the former receiving double the quantity of nitrate of soda, the latter showed .59 per cent protein above the former. The results for the entire period show that increasing the available nitrogen of the soil had no general influence toward increasing the protein content of the wheats, either when used alone or when used in connection with the other plant food elements.

Comparing the effect of nitric nitrogen with organic nitrogen, as dried blood, in a complete fertilizer, the following results stand for the four years:

	1908	1909	1910	1912	Average
Plat 18—Nitric nitrogen	9.24	11.32	9.99	13.45	11.00
Plat 23—Organic nitrogen	10.28	10.77	10.85	14.08	11.49

This set seems to show a very slight increase due to the organic nitrogen, but it is so slight as not to affect in any material way the quality of the grain, and the variations are such as to render it more than probable that such variations as do occur are due to other causes, possibly moisture, rather than to the nitrate present.

THE EFFECT OF INCREASING THE NITROGEN CONTENT OF THE SOIL IN THE PRESENCE OF LIBERAL AMOUNTS OF PHOSPHORIC ACID

In these trials, nitrogen in the form of nitrate of soda was used in connection with an application of phosphates, as shown in the tabulation:

Nitrogen and phosphate plats		Check plats	
Plat No.	Per cent protein	Plat No.	Per cent protein
10	10.93	8	11.02
10	10.93	12	10.64
8	11.02	12	10.64
18	11.00	22	11.06
20	11.92	22	11.06
Average	11.16		10.88

The average difference shows .28 per cent, an amount which is too small to be a matter of consideration for practical improvement in the quality of the grain. Further, it will be noted that such differences as do occur did not run always in the same direction.

THE EFFECT OF PHOSPHATES

In these trials the superphosphate used was from treated rock and the amounts used are given in the scheme previously shown.

Superphosphate plats		Check plats	
Plat No.	Per cent protein	Plat No.	Per cent protein
12	10.64	11	9.99
8	11.02	2	11.08
10	10.93	6	11.00
16	10.57	2	11.08
20	11.92	18	11.00
19	11.35	15	10.94
22	11.06	13	10.82
Average	11.07		10.84

In general, the phosphates as here shown appear to have had a slight tendency toward increasing the total protein, but it is very slight on the average. In five cases out of seven, however, the phosphate plats carried somewhat higher protein than did the check plats. A more extended study, however, will be required before any definite conclusion can be reached.

THE EFFECT OF POTASH

In these trials the potash was universally used in the form of sulfate in the amounts indicated in the general tabulation.

Potash plats		Check plats	
Plat No.	Per cent protein	Plat No.	Per cent protein
5	10.99	2	11.08
9	11.91	6	11.00
13	10.82	14	10.77
15	10.94	5	10.94
19	11.35	18	11.00
Average	11.20		10.96

There is shown a slightly increased protein content on the potash plats over the corresponding checks. Three out of the five cases show a higher protein content on the potash plats than on the checks, and one shows the same percentage on both plats. The difference is so small in the average that it might easily be due to difference in the moisture content of the soil, but data along this line as relating to these plats are not at hand, and therefore it would be unwise to attempt to draw conclusions until such data are secured.

THE EFFECT OF GREEN MANURE CROPS

Plats 23, 24, and 25 have had legumes grown upon them every third year and cereal crops the other year of the rotative period, with superphosphates and potash added the second year after the legume. Comparing the result from these plats for the short period the trials have been under way with the average of the check plats, and with the average of those on either side, the following results appear:

	Per cent protein
Plats with legumes	11.06
Average of all checks, no legume	11.02
Average of two nearest checks, no legume	10.90

It is not apparent that any material change in protein content has been effected by the treatment employed.

GENERAL CONCLUSIONS

The results presented in the foregoing pages seem to warrant the following conclusions:

First—There are important seasonal, varietal, and individual variations in wheat plants with respect to protein content.

Second—The principal factor causing the most pronounced variation in the protein content of wheats is climate, particularly the moisture supply in the later growing period of the crop.

Third—The tendency of wheat kernels to change from a glutenous to a starchy condition is not a constant one, but is mainly dependent upon the individuality of the plant and upon seasonal influences, particularly moisture supply in the latter part of the growing period of the plants.

Fourth—In wheats 100 per cent of which are entirely starchy there may be a reversion to an entirely glutenous condition in a single season, or the reverse may occur, dependent upon the seasonal condition.

Fifth—Allowing the grain to stand on the straw in the field until fully ripe does not materially affect the protein content.

Sixth—The protein content of wheat is affected by the time of seeding, the product of late seeded grain having a higher percent of protein than that of early seeded grain.

Seventh—The protein content of wheat is very largely influenced by the water content of the soil in the later period of its growth, and the effect of either irrigation or rainfall during this period is to lower its protein content.

Eighth—The percentage of sunshine which the grain receives during its period of growth has a somewhat direct bearing upon its protein content, but other seasonal conditions are more important.

Ninth—Retarding the growth through cooling the atmosphere has a tendency to increase the protein content.

Tenth—The quantity of available nitrogen in the soil either alone or in the presence of other available plant foods, provided there be sufficient to supply normal growth, appear to have little, if any, influence upon the protein content.

Eleventh—The low gluten content of wheats grown in California is not due to soil exhaustion, but rather to the following causes: (1) To climatic factors which allow a long growing period; (2) to relatively early seeding; (3) to the use of varieties inherently low in gluten; (4) to a lack of selecting highly glutenous seed.

Acknowledgements: The author is greatly indebted for valuable assistance rendered in the prosecution of various parts of the routine analytical work which furnishes the basis for this paper to Miss Rachel Corr and Messrs. J. D. Rose, B. A. Madson, and E. H. Walters, and also to Messrs. A. J. Gaumnitz, H. F. Blanchard and J. T. Bearss for the careful attention to the field production of the samples.

Transmitted January 24, 1913.